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COST-BENEFIT EVALUATION OF SHORT-TERM WARRANTIES FOR HOT MIX ASPHALT PAVEMENTS

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COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH BRANCH

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16. Abstract

The purpose of this report is to provide the reader with the ten-year analysis for the cost-benefit of hot mix asphalt projects constructed using the three and five-year warranty specifications developed by CDOT. There were eight projects evaluated using the three-year warranty specifications and two projects evaluated using the five-year warranty specifications. Each warranty project was evaluated with a comparable non-warranty (control) project. Overall, 214.6 lane-miles of warranty projects were constructed and compared to 276.6 lane-miles of control projects.

Implementation:

After ten years of comparison performance information between the warranty and control projects, the three and five-year, short-term warranty pavements had a rougher ride, slightly deeper ruts, a few more transverse cracks, and slightly less longitudinal cracking. The initial cost to construct the warranty projects was $12,635 per lane-mile more than the control projects. This cost could be reduced by about $5,548 per lane-mile if CDOT were to eliminate the Pavement Evaluation Team and the need to construct weigh-in-motion stations. As of January 1, 2012, the average annual cost of maintenance for the warranty projects was $5,616 per lane-mile less than the control projects. There is a shift in risk and responsibility as a result of the warranty projects, but there was no tangible benefit in extended life identified. Based on the evaluation of these pavements, the implementation of short-term warranties of HMA is currently not a cost-effective tool for CDOT.

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EXECUTIVE SUMMARY

In this report, 10 pairs of warranty and control projects were studied to assess their relative cost and benefit as of January 1, 2012. These three and five-year warranty projects were constructed between 1998 and 2003. Their current performance life averages 10 years. Each set was carefully selected so that the projects had similar characteristics in terms of pre-overlay repair work, functional class, design life, and other features in order to minimize bias. Overall, 214.6 lane-miles of warranty work were constructed. Their cost and performance was compared to 276.6 lane-miles of control work.

The initial cost to construct warranty projects and monitor them over the specified warranty period was $12,635 per lane-mile more than the control projects. However, this could be reduced by about $5,548 per lane-mile if CDOT were to eliminate the Pavement Evaluation Team and the need to construct weigh-in-motion stations. As of January 1, 2012, the average annual cost of maintenance for the warranty projects was $5,616 per lane-mile less than the control projects. However, the trend line for the warranty projects increases at a much greater rate. This increased rate might be due to the lack of early preventive maintenance measures. During the period of the warranty, no maintenance costs were borne by CDOT forces. The PET required corrective work on three of the warranty projects at no cost to CDOT.

After completion of the projects, in a post-construction survey, the contractors mentioned that they would do very little differently. It is likely that the bidding results and the construction processes on these warranty projects were similar to many of CDOT's standard projects.

For the ten warranty projects that have been constructed, three of them had experimental features added by the contractor. On I-25 at Fountain, the contractor did research to evaluate a variety of methods to minimize reflective cracking. On I-25 North of Pueblo, there was an experiment done with the longitudinal joint construction and use of recycled asphalt pavement. On I-70 at Eagle, there was an evaluation of joint tape to improve performance of longitudinal joints. The contractors on the control projects had no experimental features.

After ten years of service life, the warranty pavements had an average IRI of 79.7 inches per mile while the control pavements had an average of 70.2 inches per mile. The warranty segments had an average rut depth of 0.22 inches while the control segments had an average of 0.17 inches. The warranty segments had an average of 13.8 transverse cracks while the control segments had an average of 9.9 cracks. The warranty segments had an average of 314 linear feet of longitudinal cracking while the control segments had an average of 337 linear feet.

In conclusion, after 10 years of comparison performance information between the warranty and control projects, the three and five-year, short-term warranty pavements had a rougher ride, slightly deeper ruts, a few more transverse cracks, and slightly less longitudinal cracking. The warranty projects cost more to construct but less to maintain. The average cost/benefit ratio was 1.16. There is a shift in risk and responsibility as a

result of the warranty projects, but at this time, there was no tangible benefit identified. Based on the evaluation of these pavements, the implementation of short-term warranties of HMA is currently not a cost-effective tool for CDOT to implement.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 Background and Purpose

Over the past 10 to 20 years, the use of warranties on roadway construction projects has been viewed as an alternative to the standard practice of state highway agencies (SHA). 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 delivered to produce the best possible final product.

Methods based specifications are used in situations where the scientific reason that a particular product feature 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 CDOT for overlaying a pavement using grading SX hot-mix asphalt (HMA). 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 the specific procedure to be used by the contractor in placing such overlays (temperature limitations). Based on experience, this procedure is known to be correlated with good overlay performance over the service life of the pavement.

Methods based specifications have both advantages and disadvantages. 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, is relatively short compared to the expected service life of the finished HMA product which is generally 10 years. These specifications do require that CDOT 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 where the long-term 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 example, on an overlay project, CDOT specifies 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 long-term 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. Material property based specifications also offer some opportunities for contractors to be innovative with respect to the construction processes used to meet the required material specifications. However, while encouraging innovation, these specifications still provide no opportunity or motivation to contractors regarding the outcome of the final product.

The effectiveness of material property based specifications can be compromised by properties of the finished product that are most indicative of long-term performance compared to which properties can reasonably be measured during construction. As the understanding of pavement behavior increases, instrumentation and other technologies expand, thus, the parameters change. 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 method as well as material properties. This approach is used when certain aspects of the behavior are known to correlate with measurable properties of the material, while other aspects of the behavior are only known to be produced when specific construction procedures are followed. Currently several CDOT processes use a combination of method and material property based specifications which may yield the best end results. For example, one CDOT specification of overlaying a pavement with HMA grading SX, the specifications describe the minimum surface and air temperature to be followed in placing the overlay and the contractor's requirements if the overlay is placed below minimums.

Currently, the way projects are typically bid by CDOT provides contractors with little opportunity for innovation. Contractors have few opportunities to deviate from standard specifications and, providing that the specifications are met, are not liable if a roadway is found to be defective once it is placed in service. The current CDOT specifications are designed as a method and material based specification to yield a pavement that performs in a way which ensures the most cost-effective project to the public. A new approach, using warranties, would specify the desired outcome.

Under a warranty specification, the contractor is allowed to use innovative practices to provide the desired quality during construction. By removing some of the prescriptive specifications such as the performance grade of asphalt cement binder and gradation of the aggregate, contractors are encouraged to be innovative and develop new means and methods for longer-lasting pavements. By placing the responsibility (and risk) into the contractor's hands, the contractor is more motivated to follow good construction practices.

There is an increased awareness that contractors should be more responsible for the quality and the durability of their work. The purpose of the warranty is to incorporate a mechanism into the bidding process that would allow a better technical solution and a higher quality of work.

The goal of instituting short-term warranties on projects is to improve the quality and durability of HMA by allowing a longer timeframe to accept the work. Using this philosophy, the contractor is held liable for the performance of his product within specific distress thresholds for which the contractor has control. With short-term warranties, the quality control during construction is shifted to the contractor thereby decreasing the overall level of CDOT resources needed for project delivery.

By specifying a short-term warranty, any deficiencies related to construction or material properties of the HMA are the responsibility of the contractor while under warranty. At the very least, these warranty projects should perform as well as the pavements constructed with standard construction practices while providing safe and comfortable rides over their design lives at reasonable costs.

In practice, there was a great deal of caution among SHAs in adopting any warranty projects because a small number of assessments on the cost-effectiveness have been performed. Before 1991, the Federal Highway Administration (FHWA) restricted the use of warranties because the FHWA considered them to be an extension of routine maintenance operations and routine maintenance work was excluded from federal funding. On an experimental basis, the 1991 Intermodal Surface Transportation Efficiency Act permitted warranty projects using Federal-Aid funds. Warranty projects were advanced through the FHWA Special Experimental Program (SEP #14 – Innovative Contracting) on new or rehabilitation projects.

On May 21, 1997 the Colorado Senate approved Senate Bill 97-128. The Senate Bill established a pilot program for the warranty of HMA projects. A copy of the Senate Bill is in Appendix A. Under SEP #14, coordination was required with the FHWA. The letter obtaining the FHWA approval is dated November 8, 1999 and is in Appendix B.

The purpose of this paper is to evaluate the cost-effectiveness of the CDOT short-term warranty projects over their 10 year design life using selected measures of effectiveness.

1.2 Types of Warranties

There are a variety of pavement warranty types. The terms of the warranties commonly range from one to 10 years. The purpose of the warranty depends on who takes on a specific set of duties and the risks associated with each of those tasks. Whoever accepts responsibility agrees to take the resulting cost in case of premature distress. The risk can be transferred from the owner to the contractor to various degrees.

Some examples of items that need to be included in the risk allocation are traffic, inflation, and subgrade (pavement design). Historically, CDOT has taken the responsibility of all of these items. Depending on the type of warranty, CDOT will likely remain responsible for a majority of these items.

Following are four different types of warranties:

- Prepaid maintenance warranties,

- Workmanship warranties,
- Materials and workmanship warranties, and
- Performance warranties.

This report focuses on the pilot projects constructed with Materials and Workmanship Warranties. Using this type of warranty, the contractor is responsible for correcting defects in work elements within the contractor's control during the warranty period, including distresses resulting from defective materials and workmanship. The owner is responsible for the pavement design. The contractor assumes no responsibility for pavement design or those distresses that result from the design. Some responsibility is shifted from the owner to the contractor for materials selection and workmanship. This encourages good quality construction up front because of the consequences later on. It would motivate a contractor to use the "A" paving team on a warranty project. This is the type of short-term warranty (3 to 5 years) that CDOT has developed for HMA.

In order to obtain the best possible chance of success with the short-term materials and workmanship HMA warranty, a joint CDOT and industry task force was created in late 1999. Warranty criteria were selected from an analysis of average-performing HMA pavements that were 3 to 5 years old. From this evaluation, a distribution of performance was determined and the task force set warranty thresholds for distresses along with recommendations for the repair of these distresses. This group also developed Project Selection Guidelines. These guidelines were developed by the task force to be referenced by CDOT designers in the selection of candidate projects for short-term warranties. The criteria used to select short-term warranty projects are as follows:

- The primary scope of the project should be paving with at least 20,000 tons of HMA.
- A 3 or 5-year warranty term was recommended for projects that were designed for at least 10 years and no more than 20 years of service life.
- A Weigh-In-Motion station should be installed on or near the project unless a current station exists in the vicinity.
- A mandatory pre-bid meeting should be held with all the prime contractors bidding on the warranty project.

A total of 10 pilot projects were constructed from 1998 to 2003 by CDOT under this Senate Bill along with the assistance from the FHWA. Table 1 contains a list of HMA materials and workmanship warranties projects constructed by CDOT.

Table 1. Summary of CDOT HMA warranty projects

Location	Project Number	Milepost (from – to)	HMA Placed (inches)	Date Awarded	Date Accepted	Warranty Length (years)
I-25, Fountain - South	IM 0252-312	124.0 – 127.9	4	5/7/1998	7/28/1998	3
C 470, Santa Fe to Wadsworth Blvd.	NHS 4701-085	13.9 – 16.9	2	3/18/1998	8/20/1998	3
US 36, E & W of Superior	C 0361-157	40.0 – 44.5	2	2/26/1998	8/18/1998	3
I-25, North of Pueblo	IM 0251-157	114.7 – 120.0	4	2/14/2000	12/27/2000	3
I-70, Eagle - East	IM 0702-222	147.0 – 158.9	2	12/1/2000	10/10/2000	3
US 50, East of Kannah Crk.	NH 0501-038	46.0 – 53.3	6.75	11/16/2000	6/14/2002	3
SH 63, South of I-76	STA 0631-008	45.1 – 53.2	4	5/7/2002	11/13/2002	3
I-25, Ray Nixon – South	IM 0252-346	120.0 – 124.2	4	3/1/2002	12/11/2002	3
US 36, East of Byers	STA 0362-026	119.0 – 129.6	4	8/9/2002	8/6/2003	5
US 287, North of Ted's Place	NH 2873-126	356.2 – 364.8	2	3/3/2003	8/25/2003	5

The three-year warranty specification used on the first three projects constructed in 1998 can be found in Appendix C, the three-year warranty specification employed on the 2000 and 2002 projects is located in Appendix D, and the five-year warranty specifications utilized on the last two projects is in Appendix E.

Following the implementation of the HMA warranty program, CDOT extended the process to Portland Cement Concrete Pavement (PCCP) with a five-year warranty period. A total of three pilot projects were constructed in PCCP in 2002 and 2003. CDOT also extended the process to epoxy pavement marking material. A total of two pilot epoxy pavement marking material projects with a two-year warranty were constructed in 2003. None of these projects are included in this paper.

1.3 Warranty Limitations

Under a materials and workmanship warranty, the contractor still may not be responsible for many pavement defects, including rutting. The warranty would be terminated if the cause of rutting was due to the traffic load on a warranty project exceeding the design traffic load during a specified interval. In order to monitor the traffic load, a weigh-in-motion (WIM) station is required on warranty projects unless a WIM is located nearby

The contractor agrees to correct, at the contractor's expense, pavement defects caused by those work elements within the contractor's control. The exact cause of premature failure is frequently the result of multiple causes. Some of these may have been the responsibility of the contractor and others may have been the responsibility of the owner.

1.4 Bonding Practice

Bonding is currently used by CDOT 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 CDOT and 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. Any flaws related to materials and workmanship revealed during construction is 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 bonds are required on all major CDOT contracts (in an amount equal to the estimated project cost); the bonding requirement effectively insures only "qualified" contractors can bid on projects. Presuming that CDOT 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 determined. The period of exposure is limited to the physical completion of the project.

Major issues that were addressed since bonding has been used on warranty roadway construction projects include:

1) Limiting the risk of failure for the type of project given the historical performance. Bond companies need to have some idea of the risk of the venture they are underwriting.
2) Determining what remedial action will be required if the warranty specifications are not met and who will determine what these remedial actions will be. Bond companies need to have some idea of the magnitude of the financial obligation that they and the contractor could face.
3) Creating mandatory prebid meetings with contractors in Colorado to ensure an understanding of the design and quality control efforts necessary for these projects.

These concerns were addressed on warranty jobs to "protect" the public's investment. Such protection has been provided by using some form of bonding system similar to the current one

used, or by withholding some of the payment for the project pending its satisfactory performance during the warranty period.
CDOT's current solution to the problem of using up the bonding capacity of contractors under a warranty system is for the contractor to increase the bonding capacity. This action may 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 contractor's assets.

Consistent with current practice, funds for warranty based contracts are distributed to the contractors piecemeal as the work is completed and as the stipulations of the contract are met. A bond is posted to guarantee any remedial work required during the warranty period is performed.

After September 11, 2001, bond companies were hesitant to enter into any 3 to 5 year agreements with the contracting community. This risk was transferred to the contractor. Typically, CDOT awarded these post 9-11 projects to the larger contractors with the contractor creating a cash bond for the stipulated amount.

1.5 Benefits and Costs

The potential benefit offered by the short-term warranty for highways can be equal or better quality roadways built at lower costs than are presently being incurred. This paper documents the cost-effectiveness (benefit) of CDOT's three and five-year warranties on HMA projects constructed between 1998 and 2003. The supposed benefits to CDOT for using HMA warranties include:

- Improved materials quality and construction quality.
- Reduced requirements for CDOT supervision and material testing.
- Accelerated construction without giving up workmanship.
- Elimination of early maintenance costs.
- Encouragement of innovation.
- Addresses the industries concern to provide production flexibility and use of innovative products or procedures.

The CDOT warranty projects have additional costs over and above the typical projects that are bid. These increased costs may be due to potential warranty work and lane rental fees, and the additional costs of the bond for the term of the warranty. These costs are real and are often considered the cost of the contractor taking on more responsibility. These costs could be viewed more properly as a mechanism that encourages greater allocation of resources at initial construction in order to minimize resources that would otherwise be spent on maintenance in the future. The contractor has the responsibility for material selection, mixture design, and production, as well as all the sampling and testing requirements during construction. On the other hand, there may also be some savings to contractors. Removing prescriptive specifications may allow contractors to improve efficiency.

CHAPTER 2: ASSESSMENT PROCEDURE

2.1 Cost-Benefit Analysis

The cost-benefit analysis (CBA) estimates and then totals the equivalent monetary value of the benefits and costs of the warranty and control projects to establish if the warranty projects are worthwhile. The projects in this study have a wide range of widths and lengths making a simple comparison difficult. In order to evaluate projects on an equal basis, all the benefits and costs are expressed in terms of dollars per lane-mile. The assessment of the CBA for warranty projects are comprised of the following steps:

- First, pavement selections using warranty specifications and control bidding processes are established to form comparison sets.
- Second, the costs for initial construction, maintenance, and user are calculated for each warranty and control project in the comparison set.
- Third, the benefit of reduced CDOT forces is estimated on a warranty project.
- Fourth, the benefit is estimated in terms of extended service life based on average pavement performance for each warranty project.
- Finally, a ratio using both the net cost minus the net benefit (savings) of the warranty project is the compared to the net cost of the control project. A ratio greater than 1.0 means that the cost of a warranty project exceeds the cost associated with the control project and is not worthwhile. Detailed calculations with each step are provided in the chapter for the project. An example is provided below:
    - ◊ Initial construction for the warranty was $75,000 per lane mile while the control was $65,000 per lane mile.
    - ◊ Warranty maintenance costs were $4,000 per lane mile.
    - ◊ Control maintenance costs were $5,000 per lane mile.
    - ◊ Increased service life of the warranty project was valued at $20,200 per lane mile.
    - ◊ Ratio is 0.84 ($75,000 + $4,000 - $20,200)/($65,000 + $5,000)
      Since the ratio is less than 1.0, the warranty project was beneficial.

2.2 Establishing Warranty and Control Projects Comparison Sets

In this step, the warranty projects were selected using the established guidelines from the joint task force and appropriate control projects were selected. In order to minimize any bias in the analysis, the control projects for each warranty project were selected based on their similarity in terms of traffic, project type, pre-overlay repair, overlay thickness, location, and year of construction. In most cases, the characteristics were similar, but not necessarily identical.

2.3 Estimating CDOT and User Cost

In calculating the costs for each project, the real cost at the time of construction and maintenance work was added with the user cost component when CDOT maintenance forces performed work on the comparison sets of projects. The costs were totaled from initial construction to the current date (January 1, 2012.) No rehabilitation work is intended on these projects for the next two

years. Based on the annual expense for maintenance and user cost, the tenth year of work was determined. Information in Metric projects was converted into English units for ease of comparison. All units in this report are in English.

2.3.1 CDOT Initial Construction Cost

The first item we reviewed for the initial construction cost was the unit cost of HMA. To avoid any analytical bias about the relative unit cost of warranty and control projects, pavements in each set had as much in common as possible in terms of quantities of material. Data on cost of each warranty and control project were obtained from CDOT's Cost Estimating Unit on the lowest responsible bidder for the projects. In most cases, the quantities of HMA were not comparable and we needed to develop equations that account for the increase in efficiency of production as the number of tons of HMA produced increases. We generated the curve by using the lowest HMA bid price for all CDOT projects constructed between 1998 and 2003. To fine-tune the variability in cost from year to year, the asphalt pavement index value of 165.7 from CDOT's 2003 annual construction cost index was used to normalize the unit cost data from the previous years. The data was separated into each Region to develop the equations for the economy of scale as shown in Figure 1 for Region One.

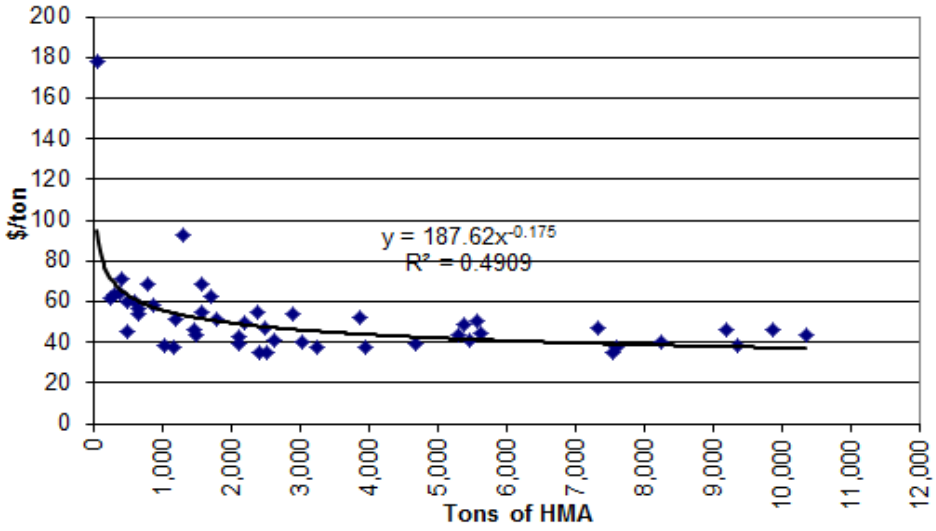

Figure 1. Region One Economy of Scale

The regional equations and fit coefficients are as follows;

Region 1	$y = 187.62x^{-0.175}$	$R^2 = 0.4909$
Region 2	$y = 163.47x^{-0.155}$	$R^2 = 0.4932$
Region 3	$y = 90.507x^{-0.104}$	$R^2 = 0.0932$
Region 4	$y = 192.08x^{-0.190}$	$R^2 = 0.6964$
Region 5	$y = 168.78x^{-0.136}$	$R^2 = 0.2916$
Region 6	$y = 170.40x^{-0.171}$	$R^2 = 0.5674$

Where

y = adjusted unit cost and

x = tons of HMA

To equalize the difference in HMA quantities between the warranty and control projects, an offset to the unit price was applied to the project with the least tonnage in the set of comparison projects. For example, if the warranty project in Region One had 8,000 tons and the control project had 14,500 tons an offset value of $3.84 per ton ($187.62 \times 8{,}000^{-0.175} - 187.62 \times 14{,}500^{-0.175}$) would be applied to reduce the bid price for the warranty project. To determine the net cost to CDOT, the revised unit cost is multiplied by the total tons on the projects.

The second item was for the cost of a warranty on the HMA over the three or five year period. This was an added cost to CDOT during the initial construction and was paid to the contractor either as a lump sum or as a cost per ton of mix placed and accepted. The first three pilot projects included the cost of the warranty in the unit cost item to place HMA. To develop the engineer's estimate for bidding purposes on the warranty project, 10% was added to the estimated cost per ton of warranted HMA. The 10% was developed based on engineering judgment and was intended to cover the contractor's costs, such as potential risks to perform warranty work, potential lane rental fees because of warranty work, and cost of warranty bond from bond insurance companies.

The third item was for the cost to construct a WIM station to monitor traffic. The WIM station monitored the traffic load on the warranty project.

The fourth item we reviewed was the cost for quality control testing. Since quality control during construction was shifted to the contractor, a CDOT tester was not specified on warranty projects. Based on a conservative daily production rate of 1,000 tons, the number of tester days was estimated. To establish the CDOT cost savings on warranty projects due to reduced staffing, a average salary of a CDOT Engineer/Physical Science Technician Level II (including overhead) of $300.00 per day was used. A loading factor of 1.35 was used to calculate the CDOT hourly rate.

The fifth item we reviewed was the cost of the pavement evaluation team (PET) during the warranty period. On an annual basis, CDOT conducted a distress survey to evaluate the performance compliance with the terms of the warranty. It took approximately one day per site to conduct one pavement performance evaluation. The cost for each evaluation included $2500 for the independent consultant to evaluate the pavement and prepare the report. For the official PET membership the CDOT staffing costs and the industry representative cost approximately $1080. Other CDOT support staff cost about $820. A loading factor of 1.35 was used to calculate the CDOT hourly rates. Traffic control for the evaluation was provided by CDOT Maintenance and was estimated to be $1000 per site for time and equipment. The annual cost for the PET was approximately $5,400.

These items were totaled. Since the length of the warranty and control projects varied, the initial cost to construct the project was determined on the basis of dollars per lane-mile.

2.3.2 CDOT Maintenance Cost

Maintenance costs may be routine or periodic, may be preventive or corrective, or may be done by the CDOT workforce or by contractors. In the case of the control projects, the maintenance responsibility of the contractor is terminated after CDOT accepts the project. For warranty projects, the contractor bears the cost to maintain the roadway for the warranty period. In computing CDOT maintenance costs, only the post-warranty maintenance period costs were considered. However, the maintenance costs associated with the control projects were determined from the CDOT acceptance date. The maintenance costs were taken from CDOT's maintenance management system (MMS) and included such items as; crack sealing, crack filling, hand patching, machine patching, and chip seal coating. Since the length of the warranty and control projects varied, the maintenance cost was determined on the basis of dollars per lane-mile.

2.3.3 Rehabilitation Cost

Rehabilitation costs are a planed cost due to structural distresses in the pavement that reduce the performance of the roadway below an acceptable level. This work is typically done by contractors. In computing CDOT rehabilitation costs, all expenditures associated with the roadway surface were considered. The costs were taken from CDOT's Cost Estimating Unit on the lowest responsible bidder for the projects. The total cost was prorated for work performed outside the original limits of the warranty or control project. Since the length of the warranty and control projects varied, the rehabilitation cost was determined on the basis of dollars per lane-mile.

2.3.4 User Cost

These costs are considered to be indirect "soft" costs borne by the facility user in the work zone as they relate to roadway condition, maintenance activity, and rehabilitation work. These costs include user travel time and increased vehicle operating costs (VOC). Though these "soft" costs are not part of the actual spending for CDOT, the costs are inherent in the cost of road repair and are included in maintenance fees. For the value of travel time, CDOT used $17.00 per hour for passenger cars, $35.00 per hour for single unit trucks, and $36.50 per hour for combination trucks. To determine the user cost, we used software developed for CDOT called WorkZone –Road User Cost. The duration of user costs were determined based on a daily single lane closure from 10:00 pm to 5:00 am in urban areas and 9:00 am to 3:00 pm in rural area. The average annual daily traffic at the time of construction was used for the traffic volume. Speed reduction was considered to be from the posted speed limit down to 45 mph in the work-zone. We estimated that about $3,000 of work by CDOT maintenance forces or contractors could be accomplished in a day. The cost of work done was divided by $3,000 to determine the number of days. Since the length of the warranty and control projects varied, the user cost was determined on the basis of dollars per lane-mile.

2.4 Estimating Effectiveness

For this report, the time scope for evaluating the CBA is based on performance from the initial construction to the current date (January 1, 2012.) CDOT's pavement management system (PMS) data for the international roughness index (IRI), rutting depth, fatigue cracking, longitudinal

cracking and transverse cracking was used in this report to estimate the performance and estimate extended life. When comparing the extended lives from these performance measures, the smallest value from the five distresses will be used as the basis for calculating the benefit. The PMS condition data is collected annually and summarized in 528 foot (0.1 mi.) sections. When the typical section is a divided highway, annual PMS data is reported in the driving lane for both directions. When the typical section is an undivided highway, annual PMS data is collected in one direction one year and the opposite direction the next year. Since 2009, PMS data was only collected in the primary direction (increasing mileposts) on undivided highways.

When analyzing the PMS data for a preventive maintenance or rehabilitation project, normal CDOT practice is to group the distress data from the tenth-mile files into half-mile segments. This report used a running average of five tenth-mile sections and used the maximum value to establish the annual performance value for the projects.

For warranty projects, the contractual threshold of performance indicators was established by CDOT to reflect minimum acceptable distresses over the warranty period. The contractor is obligated to perform remedial work if the thresholds are exceeded at any time during that period. Such distress thresholds on warranty projects are not the same minimums for rehabilitation or replacement. Given the minimum rehabilitation threshold and the performance curve, the service life can be estimated.

2.4.1 Performance Effectiveness – The International Roughness Index

International Roughness Index (IRI) is a statistic used to determine the amount of roughness in a measured longitudinal profile. IRI was used because it is a common indictor of pavement condition. The IRI is computed from a single longitudinal profile using a quarter-car simulation the quarter-car calculates the response similar to a passenger car. The simulated suspension motion is accumulated and divided by the distance traveled to give an index with units of slope (in/mi).

For this study, the performance curve for the warranty project was compared to the control project and the time interval at which the IRI between the two are the same is the extended service life. For example, a comparison of IRI in Figure 2 shows that the extended service life is over two years. However, we will round down to the whole year. This results in an extended service life of two years.

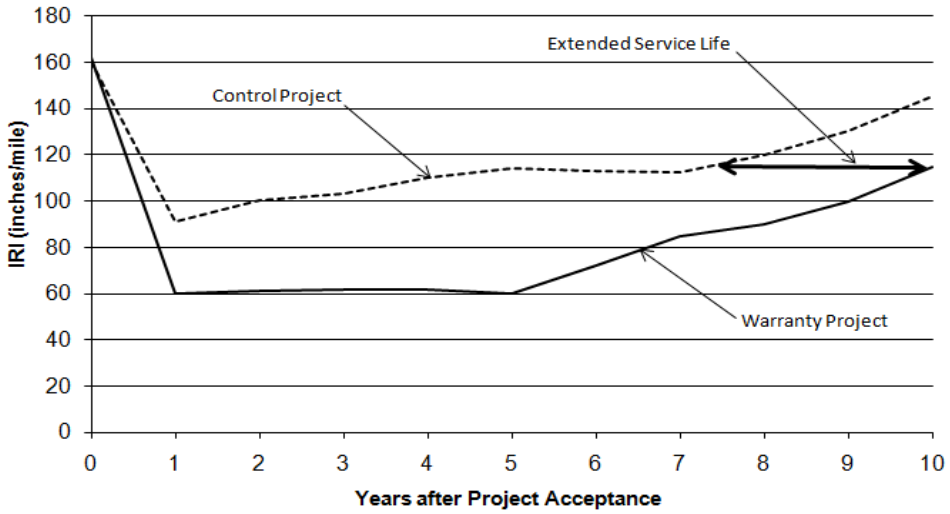

Figure 2. IRI performance curves

2.4.2 Performance Effectiveness – Rutting

The depth of a rut in the wheel path was used because it is a common indicator for rehabilitation. Rutting of the pavement could be caused by low air voids in the HMA or an underestimate of the truck traffic over the design life. Remedial action by the contractor will not be required if the accumulated truck traffic exceeds the design. Weigh-in-motion stations were installed on or near the warranty projects to monitor the truck traffic. In this research the performance curve for the warranty project was compared to the control project and the time interval between them is the extended service life. For example, a comparison of rutting in Figure 3 shows that the extended service life of a warranty project to be one year. This extended service life is probably conservative since it assumes that the rut depth for the warranty pavement will increase at the same rate as the control project.

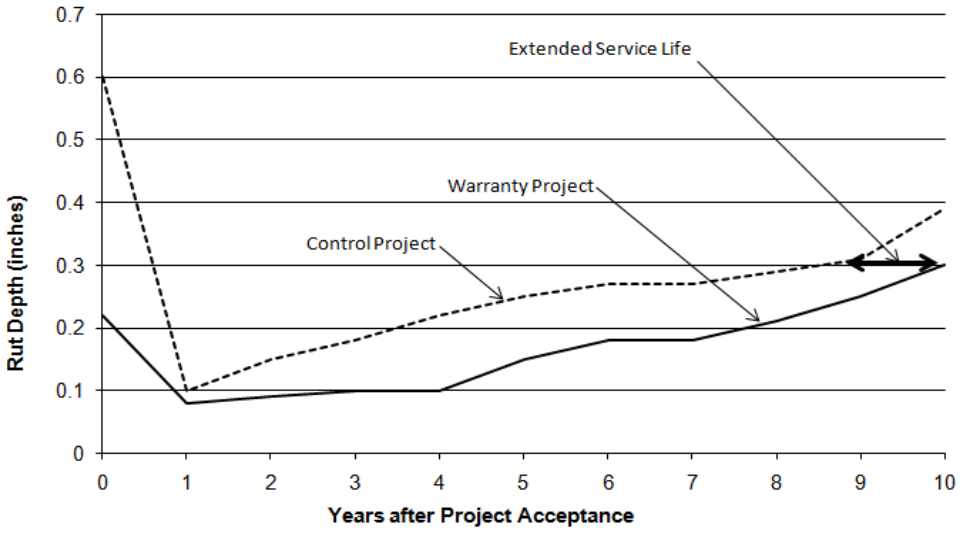

Figure 3. Rut depth performance curves

2.4.3 Performance Effectiveness – Fatigue Cracking

Fatigue cracking is caused by repeated traffic loadings usually in the wheel paths. This distress is not a measured distress under warranty. However, it was evaluated because it is the typical distress that CDOT repairs. For this study, the performance curve for the warranty project will not be used to determine the extended service life.

2.4.4 Performance Effectiveness – Longitudinal Cracking

Longitudinal cracking was evaluated because it is a good indicator for the performance of the contractor's construction of the longitudinal joint and for HMA segregation due to the paving operation. Paver segregation is difficult to visually detect at the time of construction because it is typically found just below the surface of the mat. This study compared the performance curve for the warranty project to the control project and the time interval between them is the extended service life. For example, a comparison of longitudinal cracking in Figure 4 indicates that no extended service life was found because the control project had a lesser amount of longitudinal cracking.

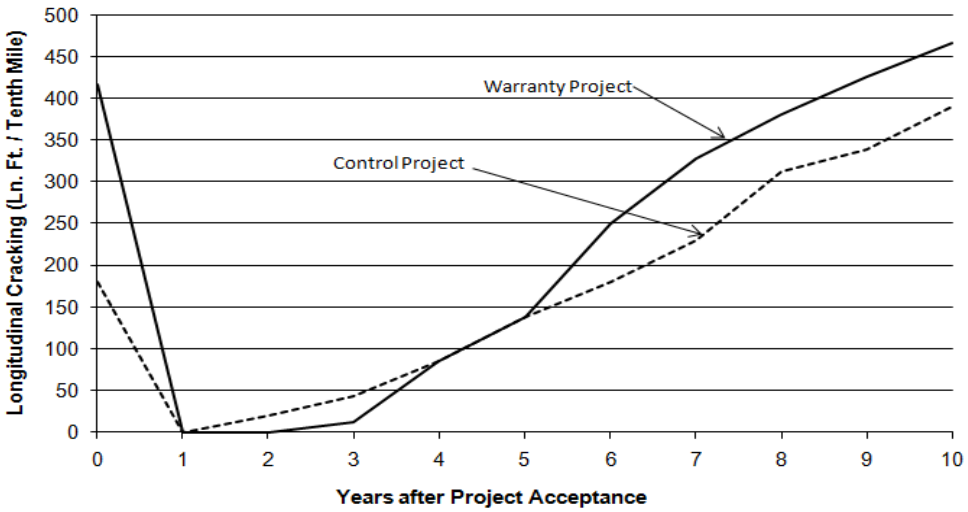

Figure 4. Longitudinal cracking performance curves

2.4.5 Performance Effectiveness – Transverse Cracking

Transverse cracking was evaluated because it is a good indicator for the performance of the asphalt cement binder's resistance to thermal cracking. This study compared the performance curves between the two projects and the time interval between them is the extended service life. For example, a comparison of transverse cracking in Figure 5 indicates that the extended service life of a warranty project to be one year.

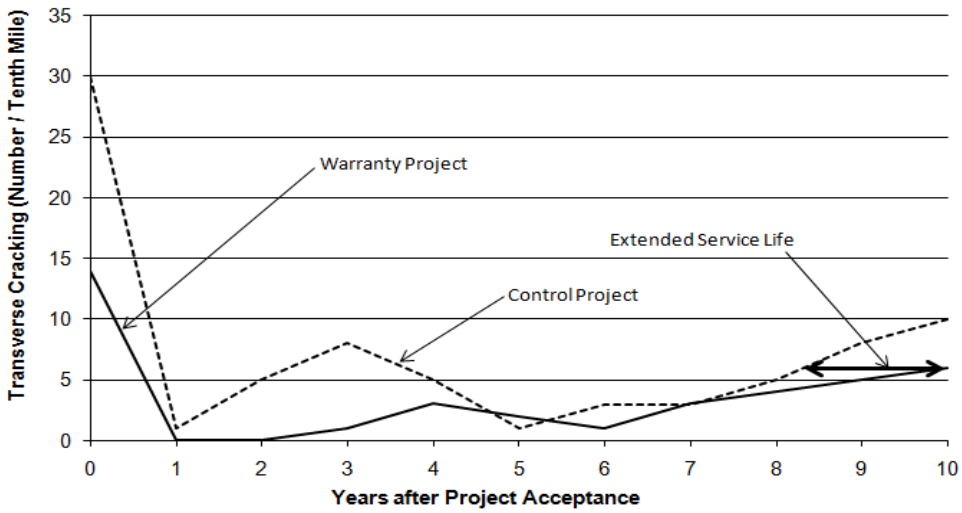

Figure 5. Transverse cracking performance curves

2.5 Extended Service Life

To maintain and manage CDOT's highway network requires capital investments to rehabilitate pavements as they approach the end of their service lives. Longer life translates into cost savings to maintain CDOT's network. In fiscal year 2011, CDOT spent approximately $151 million to rehabilitate about 750 lane-miles of the network. Therefore, to rehabilitate a lane-mile of roadway is about $202,000 for the estimated 10 years of design life. For this report, every year of extension in service life past the design life would save CDOT about $20,200 per lane-mile.

CHAPTER 3: I-25 SOUTH OF FOUNTAIN

3.1 Project Information

This warranty project is in El Paso County on I-25 and extends south from Fountain for 3.8 miles (15.2 lane miles) from Milepost 124.05 to Milepost 127.87. For reference, the Colorado project number is IM 0252-312 with a sub-account number of 12116.

The control project is in Pueblo County on I-25 north of Pueblo and extends north for approximately 6.4 miles (25.6 lane-miles) from Steel Hollow, Milepost 109 to Young Hollow, Milepost 115.4. For reference, the Colorado project number is IM 0251-154 with a sub-account number of 12528. This project was also used as the control project for the experimental project on I-25, North of Pueblo.

A comparison of the information from both the warranty and control projects is summarized in Table 2 below. The tonnage information in the following table represents the approximate quantity of HMA used to bid the projects.

Table 2. Comparison summary of the I-25 Fountain / I-25 Pueblo project

	Warranty Project	Control Project
Overlay Thickness (inches)	4	4
Rehabilitation Strategy	1”(NB) & 2-1/2” (SB) milling	2-inch milling
Award Date	May 7, 1998	January 11, 1999
Begin Construction Date	May 26, 1998	March 1, 1999
Project Acceptance Date	July 28, 1998	September 17, 1999
Facility Type	4-lane Interstate	4-lane Interstate
Tonnage	44,667	53,422
Engineer’s Estimate, $/ton	$40.82	$35.00
Bid Price, $/ton	$35.38	$32.00
Economy of Scale, $/ton	$31.09	$30.24
Offset to the Unit Price, $/ton	$0.85	N/A
Mix Gradation	S	S
Type of Binder	AC-20/PG 70-34	AC-20R
Warranty Line Item	Not Specified	NA
Weigh-In-Motion Station	Installed in 2001	NA
Quality Control Testing	($13,500)	NA
PET Review (3 years)	$16,200	NA
10-year Design ESALs	5,162,000	5,372,000
Average Annual Daily Traffic	17,300	14,500
Single Unit Trucks (percent)	4.6	4.3
Combination Trucks (percent)	7.6	7.3

3.2 Initial Construction Cost

Using the information from the previous table, the standardized unit cost of the warranty project HMA is $34.53 (35.38 – 0.85) per ton which results in a cost of $1,542,351 (34.53*44,667). In addition, it cost $16,200 for the PET reviews during the warranty period. However, it saved $13,500 in quality control testing. This resulted in a cost to CDOT of $101,648 per lane-mile (1,542,351 + 16,200 – 13,500)/15.2 to construct and monitor the warranty project. The control cost to CDOT is $66,778 per lane-mile to construct (32.00 * 53,422)/25.6.

3.3 Maintenance and User Cost

The cost of CDOT roadway surface maintenance activities is summarized below in Figure 6 for the warranty and control project as collected in MMS. As of January 1, 2012 CDOT spent a total of $8,178 per lane-mile on the warranty project while spending $8,692 per lane-mile on the control project.

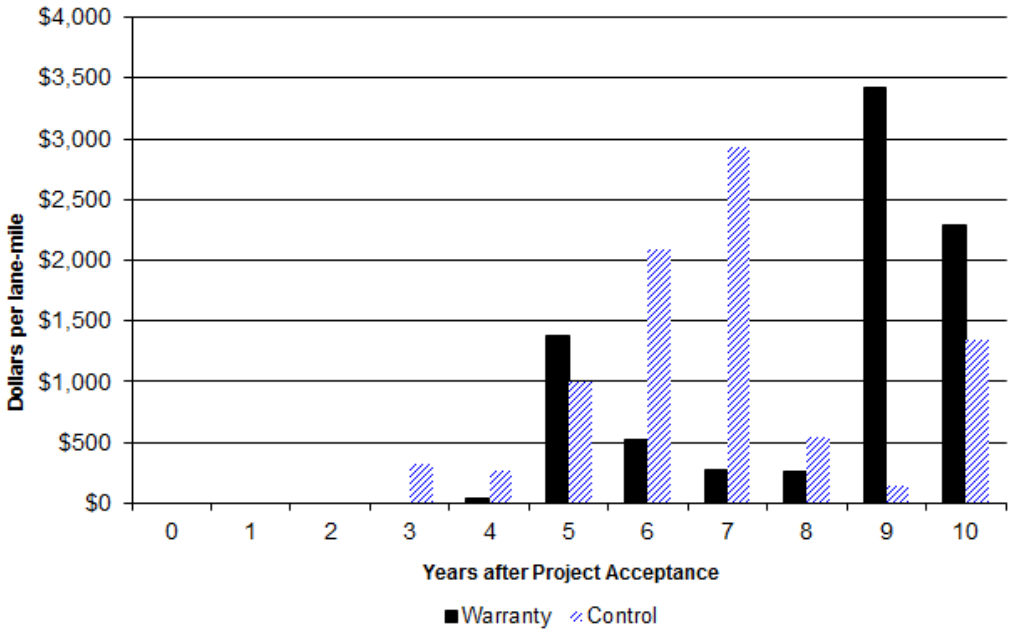

Figure 6. Comparison of the I-25 Fountain / I-25 Pueblo maintenance cost

3.4 Performance Data

The IRI performance data in Figure 7 indicates that both primary (northbound) and secondary (southbound) directions of the warranty and control projects had about the same IRI after 10 years. Based on this information, there is no expected benefit in extended life for the warranty project.

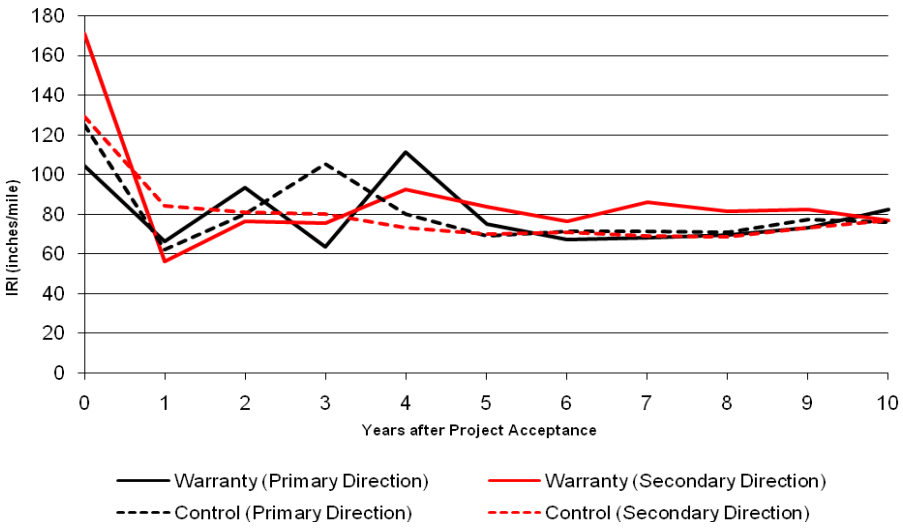

Figure 7. Comparison of the I-25 Fountain / I-25 Pueblo IRI performance

Due to some maintenance work on the control project in year nine, the rut data shown in Figure 8 indicates that the control project had slightly less rutting in 10 years after the project was accepted as the warranty project had in nine years. Based on this information, there is no expected benefit in extended life for the warranty project. The truck traffic in Figure 9 shows that the loading on the warranty project was not exceeded during the 3-year warranty period.

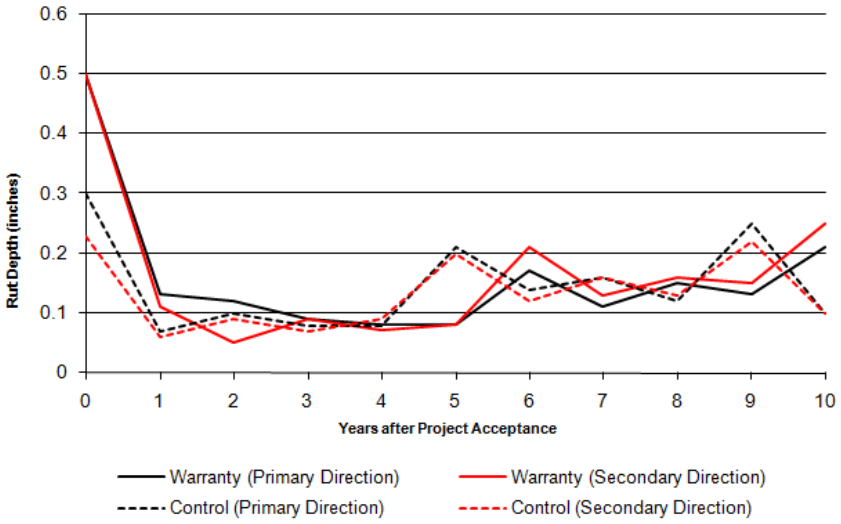

Figure 8. Comparison of the I-25 Fountain / I-25 Pueblo rut depth performance

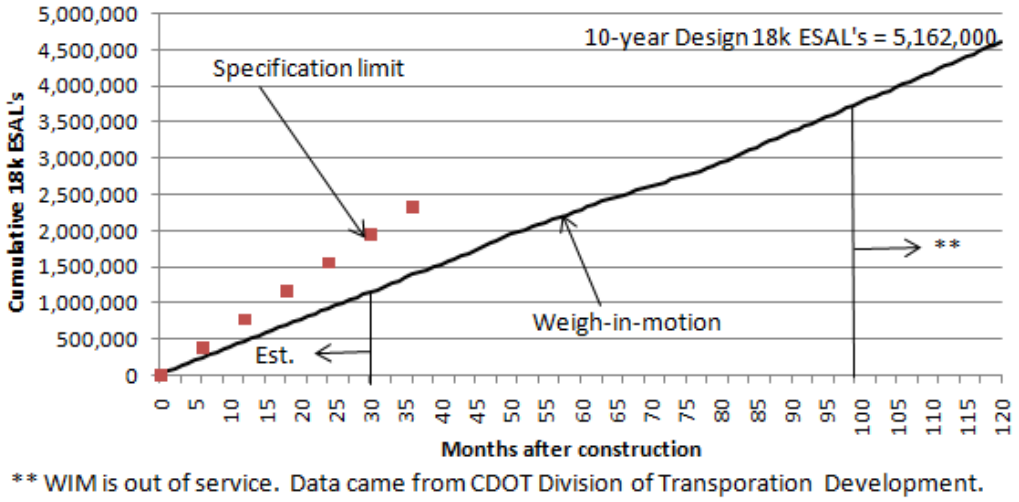

Figure 9. Cumulative Weigh-in-motion 18k ESALs on I-25 Fountain warranty project

Although fatigue cracking was not a specified distress in the warranty, we included the PMS data for information only. Figure 10 suggests that the control project had significantly more fatigue cracking prior to the rehabilitation. However, both projects had about the same amount of fatigue cracking in 10 years.

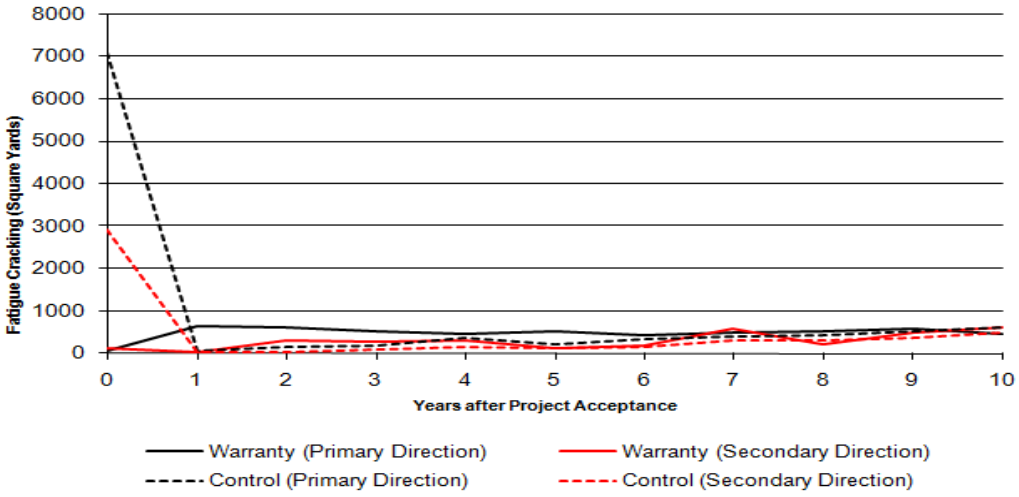

Figure 10. Comparison of the I-25 Fountain / I-25 Pueblo fatigue cracking performance

The longitudinal cracking data in Figure 11 illustrates that there is a large variability in the PMS data from year to year. While the control project had significantly more longitudinal cracking prior to the rehabilitation, the warranty project had significantly more than the control project in 10 years. Based on this information, there is no expected benefit in extended life for the warranty project.

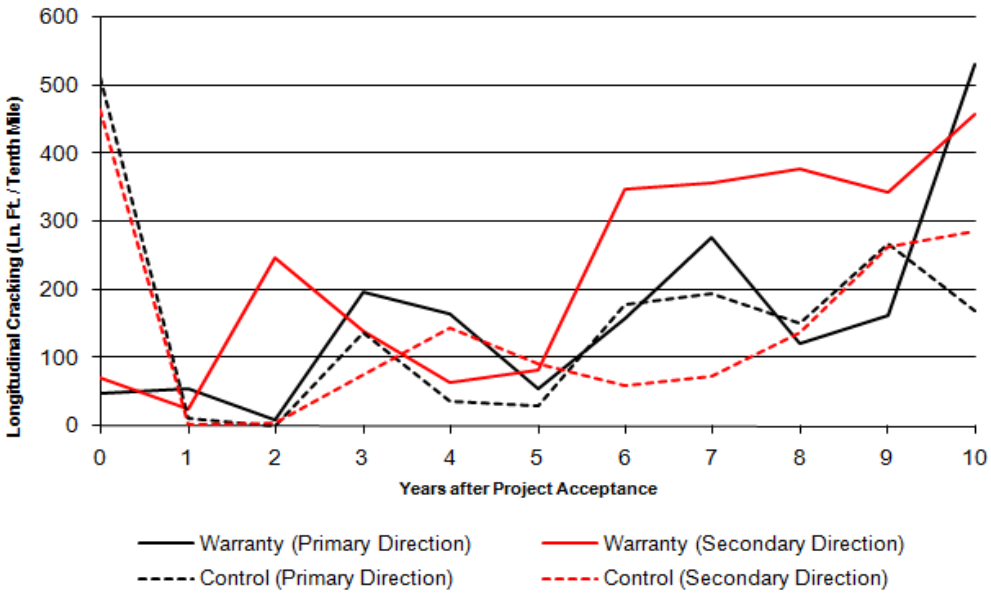

Figure 11. Comparison of the I-25 Fountain / I-25 Pueblo longitudinal cracking performance

Figure 12 reveals that both projects had about the same number of transverse cracks prior to construction. However, the warranty project had significantly more transverse cracks than the control project in 10 years. Based on this information, there is no expected benefit in extended life for the warranty project.

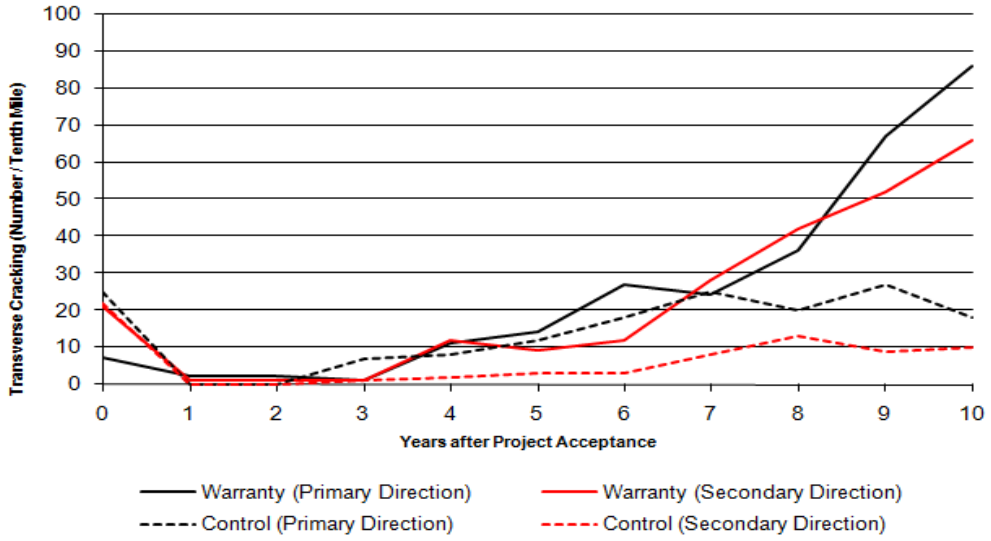

Figure 12. Comparison of the I-25 Fountain / I-25 Pueblo transverse cracking performance

3.4.1 PET Reviews

During the warranty period, three annual evaluations were performed by the PET. For the first two years the PET found all measured distresses were below the limits specified in the contract. However, in the third evaluation the longitudinal joint separation threshold was exceeded. The contractor was required to perform corrective work on the longitudinal joints.

3.5 Cost-Benefit Analysis

As of January 2012, the net cost on the warranty project is $109,826 (101,648 + 8,178) per lane-mile and the net cost of the control project is $75,470 (66,778 + 8,692) per lane-mile. Based on performance, no net benefit in extended life is expected for this warranty project. Since the ratio is 1.46 (109,826/75,470), the cost of a warranty project exceeds the cost of the control project and is not worthwhile.

CHAPTER 4: C-470, SANTA FE DRIVE TO WADSWORTH BOULEVARD

4.1 Project Information

This warranty project is in Arapahoe, Douglas, and Jefferson Counties on C-470 and extends west of Santa Fe Drive to Wadsworth Boulevard for approximately 3.0 miles (12.0 lane-miles) from Milepost 13.9 to Milepost 16.9. For reference, the Colorado project number is NHS 4701-085 with a sub-account number of 11595.

The control project is in Adams County on I-25 and extends north beginning at 84th Avenue to 120th Avenue for approximately 4.4 miles (26.4 lane-miles) from Milepost 218.70 to Milepost 223.06. For reference, the Colorado project number is IM 0253-144 with a sub-account number of 11593R.

Due to high volume of traffic, the projects were built with night paving operations. A comparison of the information from both the warranty and the control projects is summarized in Table 3 below. The tonnage information in the following table represents the approximate quantity of HMA used to bid the projects. The variation in unit cost between the two projects could be because the warranty project was adjacent to the contractor's plant.

Table 3 Comparison summary of the C-470 / I-25 project

	Warranty Project	Control Project
Overlay Thickness (inches)	2	2
Rehabilitation Strategy	½-inch milling	2-inch milling
Award Date	March 18, 1998	May 21, 1998
Begin Construction Date	May 4, 1998	June 10, 1998
Project Acceptance Date	August 20, 1998	September 24, 1998
Facility Type	4-lane Interstate	6-lane Interstate
Tonnage	19,153	26,459
Engineer's Estimate, $/ton	$38.10	$45.36
Bid Price, $/ton	$37.19	$47.63
Economy of Scale, $/ton	$31.57	$29.87
Offset to the Unit Price, $/ton	$1.70	N/A
Mix Gradation	S	S
Type of Binder	PG 76-28	PG 76-28
Warranty Line Item	NA	NA
Weigh-In-Motion Station	$55,000	NA
Quality Control Testing	($6,000)	NA
PET Reviews (3 years)	$16,200	NA
10-year Design ESALs	3,688,000	9,231,000
Average Annual Daily Traffic	85,801	151,000
Single Unit Trucks (percent)	2.1	5.5
Combination Trucks (percent)	1.4	5.8

4.2 Initial Construction Cost

Using the information from the previous table, the standardized unit cost of the warranty project HMA is $35.49 (37.19 – 1.70) per ton which results in a cost of $679,740 (35.49 * 19,153). In addition, it cost $16,200 for the PET reviews during the warranty period and $55,000 to install a weigh-in-motion station. However, it saved $6,000 in quality control testing. This resulted in a cost to CDOT of $62,078 per lane-mile (679,740 + 16,200 + 55,000 – 6,000)/12 to construct and monitor the warranty project. The cost to construct the control project is $47,736 per lane-mile (47.63 * 26,459)/26.4.

4.3 Maintenance, Rehabilitation and User Cost

The cost of CDOT roadway surface maintenance activities is summarized below in Figure 13 for the warranty and control project as collected in MMS. As of January 1, 2012 CDOT has spent a total of $86,508 per lane-mile on the warranty project while spending $118,851 per lane-mile on the control project. The high maintenance cost on these projects is due to placing stone matrix asphalt (SMA) overlay in 2005 on the warranty project and in 2006 on the control project. In 2006, the control project was resurfaced due to paver segregation distresses.

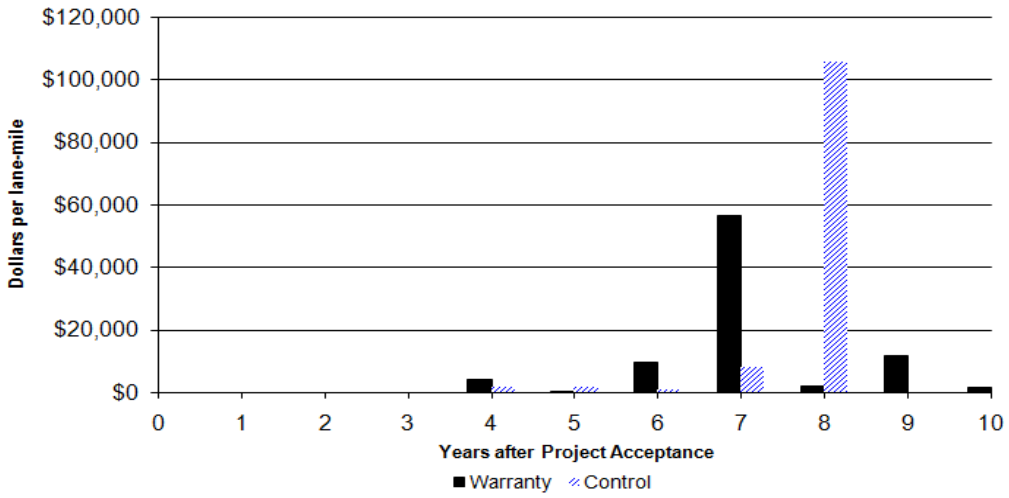

Figure 13. Comparison of the C-470 / I-25 maintenance, rehabilitation and user cost

4.4 Performance Data

After the extensive work on the warranty and control projects, the IRI performance data shown in Figure 14 indicates that both projects are performing well and there is no difference in their performance. Therefore, no extended service life could be determined for the warranty project.

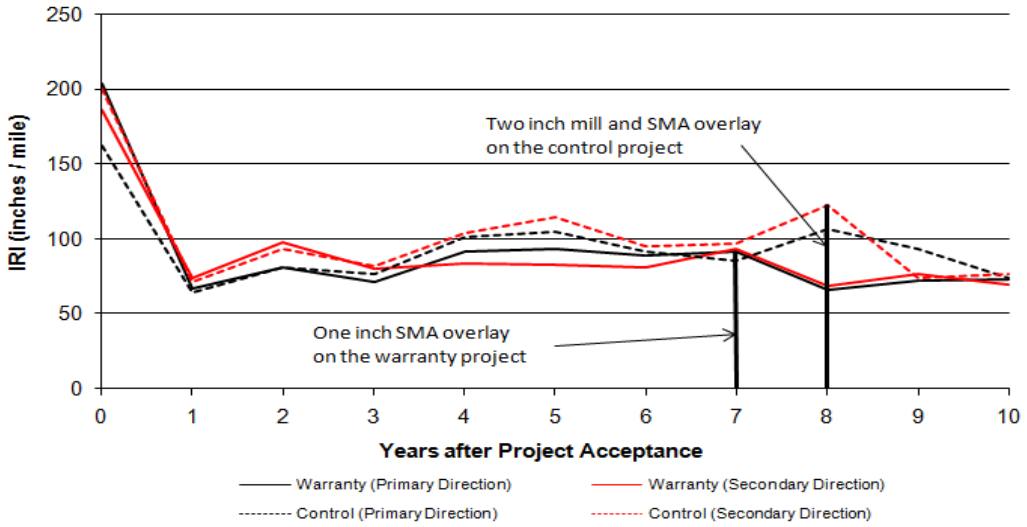

Figure 14. Comparison of the C-470 / I-25 IRI performance

Due to the large amount of work done on both projects, the rut data in Figure 15 illustrates that both projects are performing well after 10 years of service. The extended service life could not be established for the warranty project. The truck traffic in Figure 16 indicates that the loading on the warranty project was not exceeded during the 3-year warranty period.

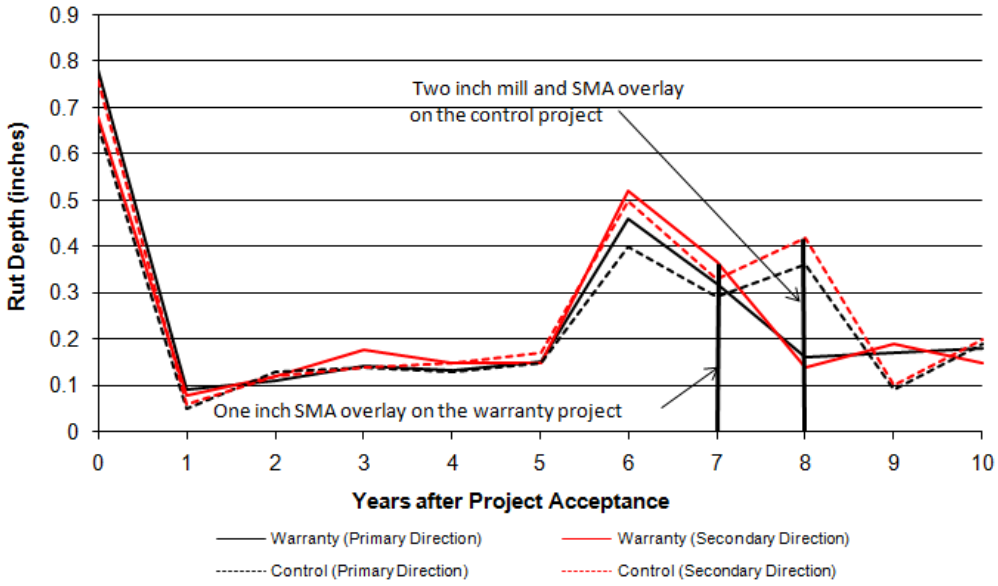

Figure 15. Comparison of the C-470 / I-25 rut depth performance

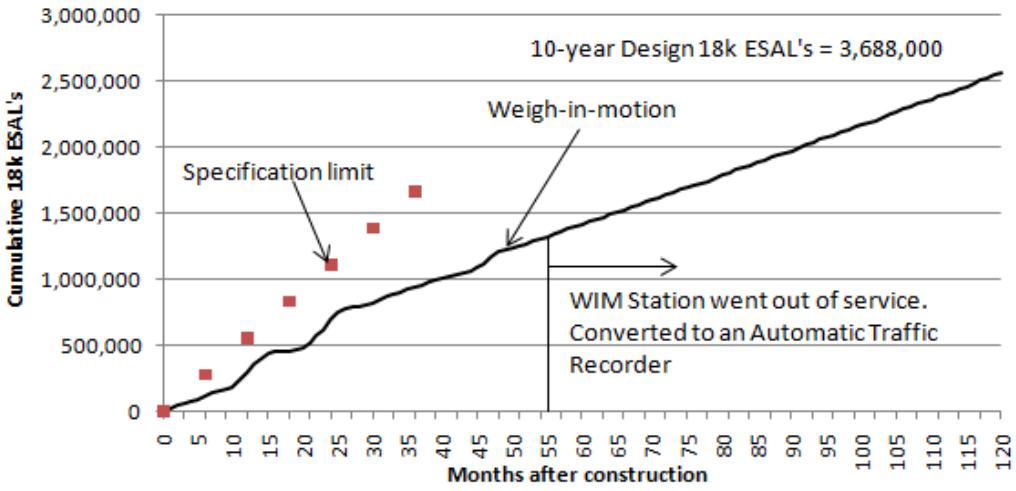

Figure 16. Cumulative weigh-in-motion 18k ESALs on the C-470 warranty project

The fatigue data is included for information only. It is not a specified distress in the warranty project. The rehabilitation of the I-25 control project in 2006 was due to paver segregation primarily in the secondary direction. Figure 17 indicates that about the same amount of fatigue cracking reappeared within three years after placing the one inch SMA overlay on the warranty project. Also, the rehabilitation strategy on the control project in the eight year after construction appears to be performing well.

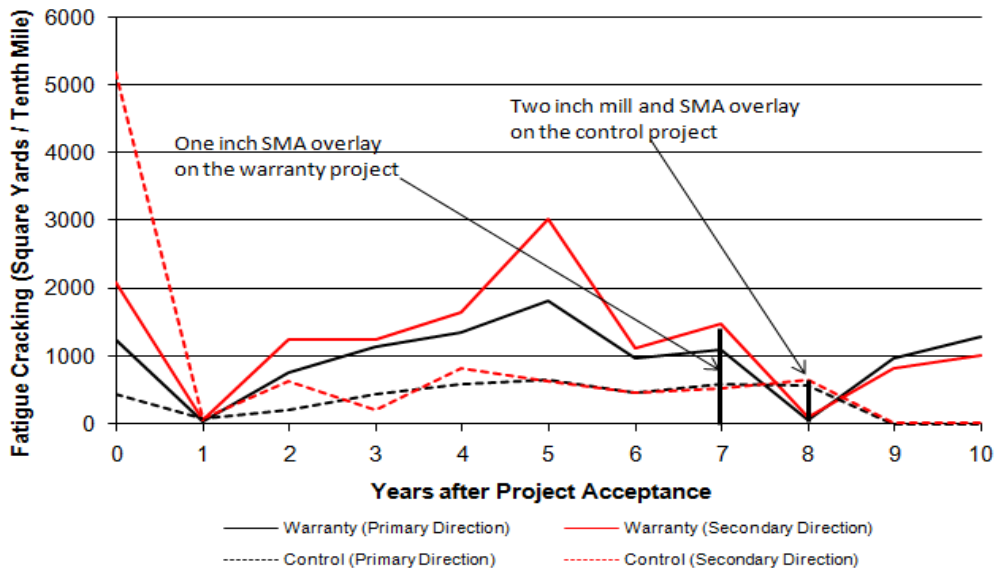

Figure 17. Comparison of the C-470 / I-25 fatigue cracking performance

The longitudinal cracking data in Figure 18 illustrates that there is a large variability in the PMS data from year to year. Due to the scatter in the PMS data, no conclusion can be made on the extended life for the warranty project.

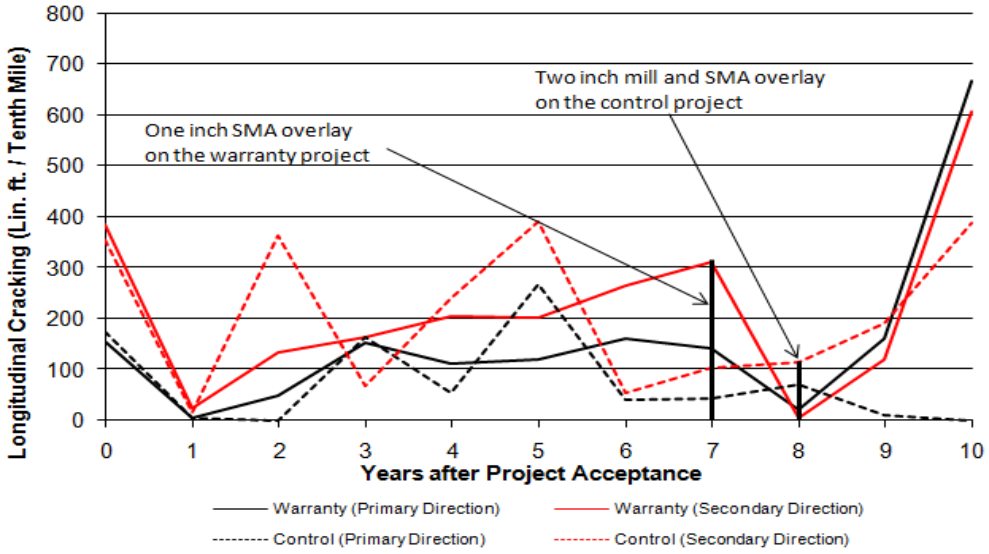

Figure 18. Comparison of the C-470 / I-25 longitudinal cracking performance

Figure 19 reveals that both projects had about the same number of transverse cracks prior to the initial construction. However, the warranty project had significantly less transverse cracks at the time it was rehabilitated and that it had an extended life of over three years. Based on this information, we rounded down and determined that there is about a three year benefit in extended life which is about $60,600 per lane-mile (3 * 20,200) for the warranty project.

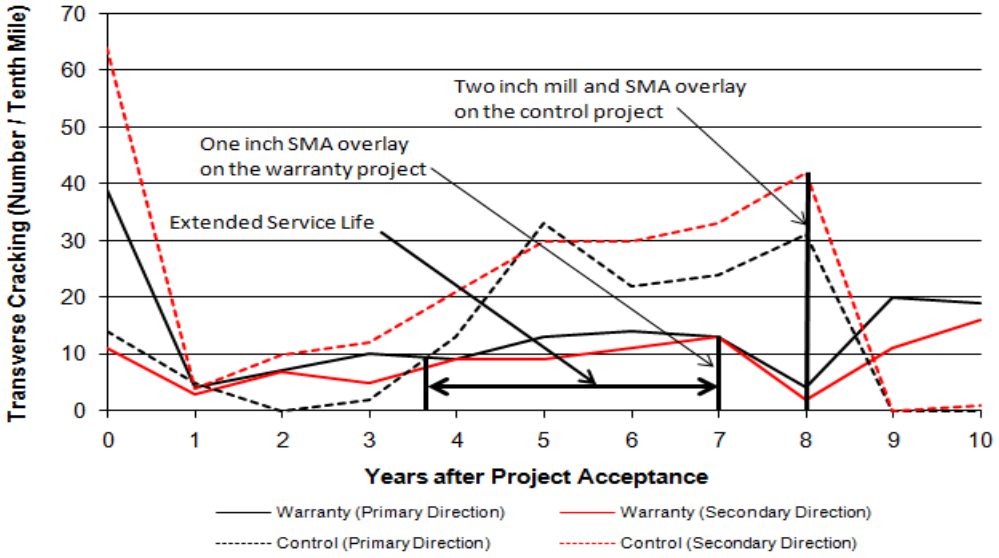

Figure 19. Comparison of the C-470 / I-25 transverse cracking performance

4.4.1 PET Reviews

During the warranty period, three annual evaluations were performed by the PET. In the third evaluation, the contractor was required to perform corrective work at 10 locations.

4.5 Cost-Benefit Analysis

As of January 2012, the net cost on the warranty project is $148,584 (62,078 + 86,506) per lane-mile and the net cost of the control project is $166,587 (47,736 + 118,851) per lane-mile. Based on all the performance data, no net benefit in extended life is expected for this warranty project. Since the ratio is 0.89 (148,584/166,587), the cost of a warranty project is less than the cost of the control project and is worthwhile.

CHAPTER 5: U.S. HIGHWAY 36, EAST AND WEST OF SUPERIOR INTERCHANGE

5.1 Project Information

This warranty project is in Boulder County on U.S. Highway 36 beginning at Cherryvale Road and extending southeasterly for 4.5 miles (18.0 lane-miles) from Milepost 40.0 to Milepost 44.5. For reference, the Colorado project number is C 0361-157 with a sub-account number of 11982.

The control project is in Morgan County on I-76 beginning west of Fort Morgan and extending easterly for approximately 16 miles (64.0 lane-miles) from Milepost 76.5 to Milepost 92.5. For reference, the Colorado project number is C 0761-170 with a sub-account number 11979.

A comparison of the information from both the warranty and control projects is summarized in Table 4 below. Both projects were built on existing concrete pavements. The tonnage information in the following table represents the approximate quantity of HMA used to bid the projects.

Table 4 Comparison summary of the US 36 / I-76 project

	Warranty Project	Control Project
Overlay Thickness	2 inches	2 inches
Rehabilitation Strategy	1-inch milling	¾-inch leveling course
Award Date	February 26, 1998	January 20, 1998
Begin Construction Date	June 21, 1998	April 29, 1998
Project Acceptance Date	August 18, 1998	July 24, 1998
Facility Type	4-lane Interstate	4-lane Interstate
Tonnage	25,393	77,157
Engineer's Estimate, $/ton	$36.74	$33.34
Bid Price, $/ton	$36.56	$35.38
Economy of Scale, $/ton	$27.96	$22.64
Offset to the Unit Price, $/ton	$5.32	N/A
Mix Gradation	SHRP ¾" Fine	S
Type of Binder	PG 70-34	AC-20R
Warranty Line Item, L.S.	NA	NA
Weigh-In-Motion Station	$77,185	NA
Quality Control Testing	($7,800)	NA
PET Reviews (3 years)	$16,200	NA
10-year Design ESALs	2,586,940	2,800,000
Average Annual Daily Traffic	74,400	16,100
Single Unit Trucks (percent)	2.2	4.2
Combination Trucks (percent)	1.0	15.9

5.2 Initial Construction Cost

Using the information from the previous table, the standardized unit cost of the warranty project HMA is $31.24 (36.56 – 5.32) per ton which results in a cost of $793,277 (31.24 * 25,393). In addition, it cost $16,200 for the PET reviews during the warranty period and $77,185 to install a weigh-in-motion station. However, it saved $7,800 in quality control testing. This resulted in a cost to CDOT of $48,826 per lane-mile (793,277 + 16,200 + 77,185 – 7,800)/18 to construct and monitor the warranty project. The cost to construct the control project is $42,653 per lane-mile (35.38 * 77,157)/64.

5.3 Maintenance and User Cost

The cost of CDOT roadway surface maintenance activities is summarized below in Figure 20 for the warranty and control project as collected in MMS. As of January 1, 2012 CDOT has spent a total of $9,854 per lane-mile on the warranty project while spending $4,317 per lane-mile on the control project.

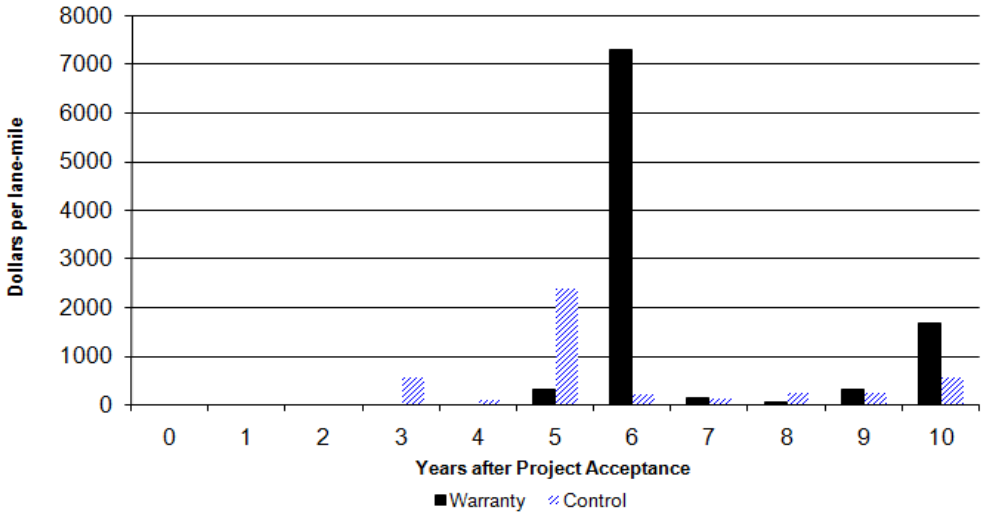

Figure 20. Comparison of the US 36 / I-76 maintenance cost

5.4 Performance Data

The IRI performance data shown in Figure 21 indicates that the warranty project had an extended service life of about two years. Based on this information, there is about a two year benefit in extended life which is a benefit of about $40,400 per lane-mile (2 * 20,200) for the warranty project.

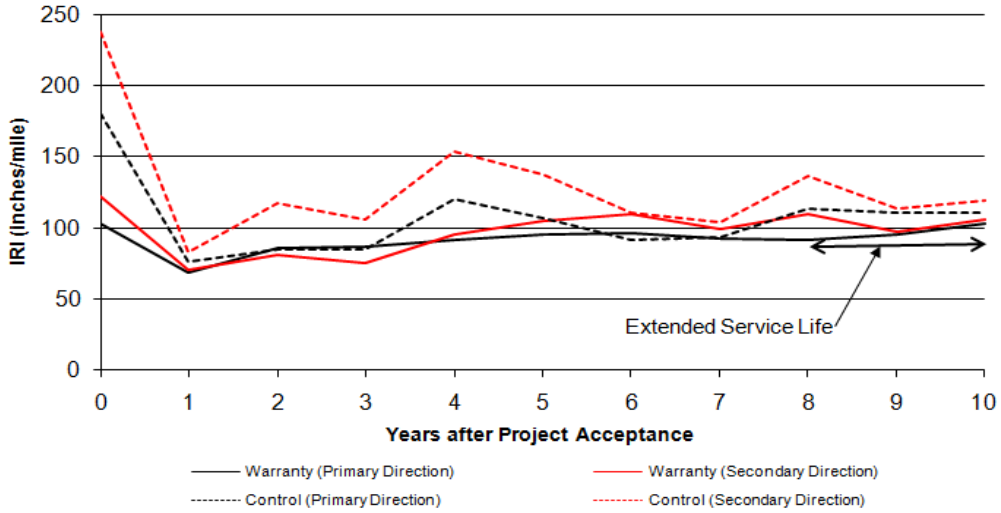

Figure 21. Comparison of the US 36 / I-76 IRI performance

In the ten years after acceptance, the rut data shown in Figure 22 indicates that the warranty project had about twice the amount of rutting as compared to the control project. Therefore, there is no expected benefit in extended life for the warranty project. The truck traffic in Figure 23 shows that the loading on the warranty project was not exceeded during the 3-year warranty period.

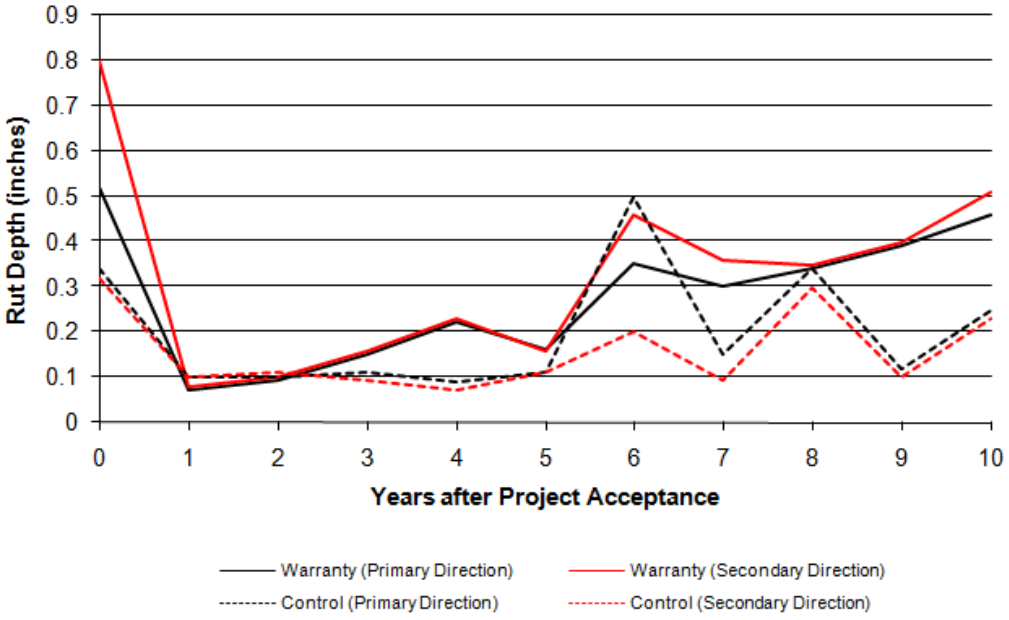

Figure 22. Comparison of the US 36 / I-76 rut depth performance

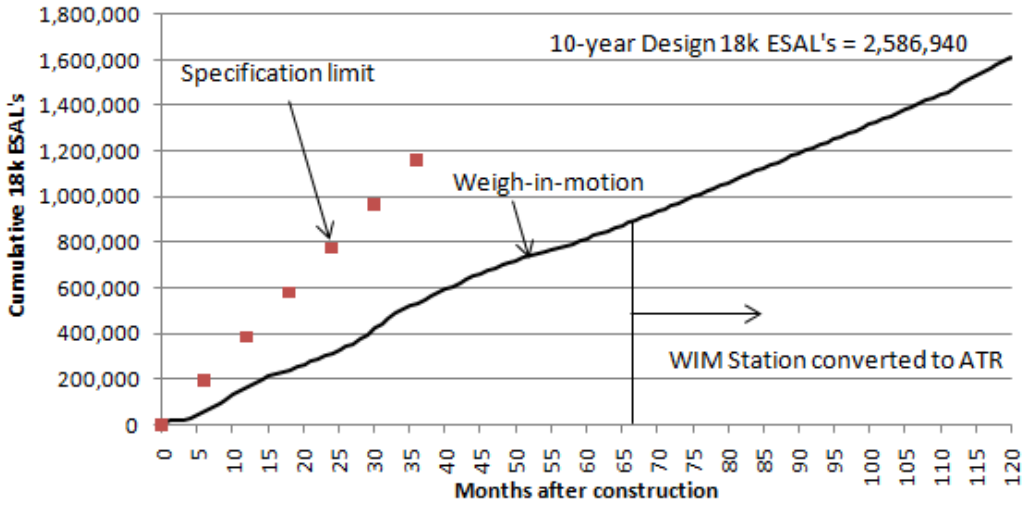

Figure 23. Cumulative weigh-in-motion 18k ESALs on the US 36 warranty project

The fatigue data is included for information only. It is not a specified distress in the warranty project. Figure 24 indicates that much less fatigue cracking was present at year zero as compared to the control project. The warranty project had a steady increase in the amount of fatigue cracking while the control project remained about the same. After ten years of service, equal performance is found in both projects.

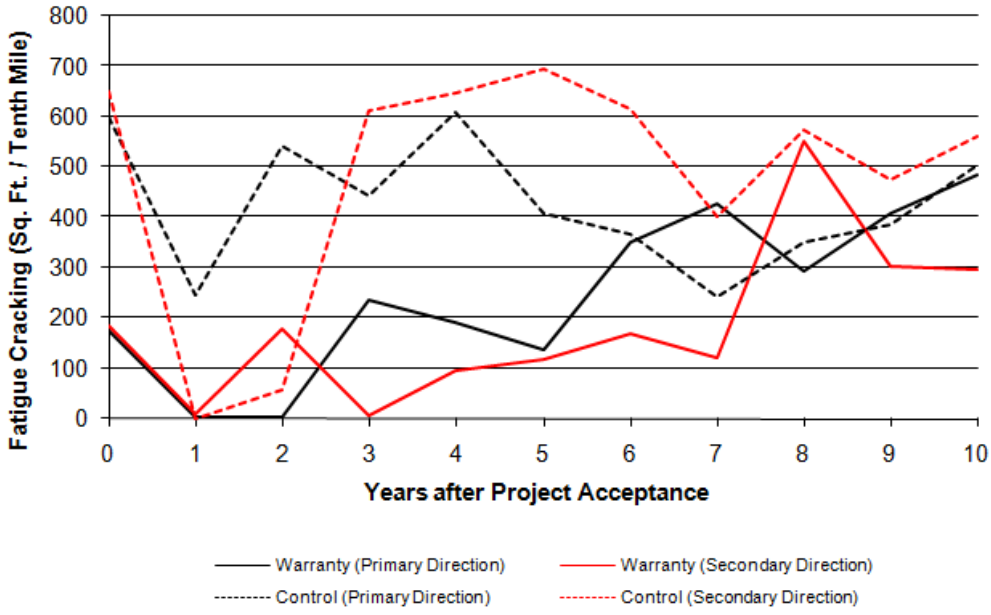

Figure 24. Comparison of the US 36 / I-76 fatigue cracking performance

The longitudinal cracking data in Figure 25 illustrates that both projects are performing about the same over the 10-year period. Therefore, no conclusion can be made on the extended life for the warranty project.

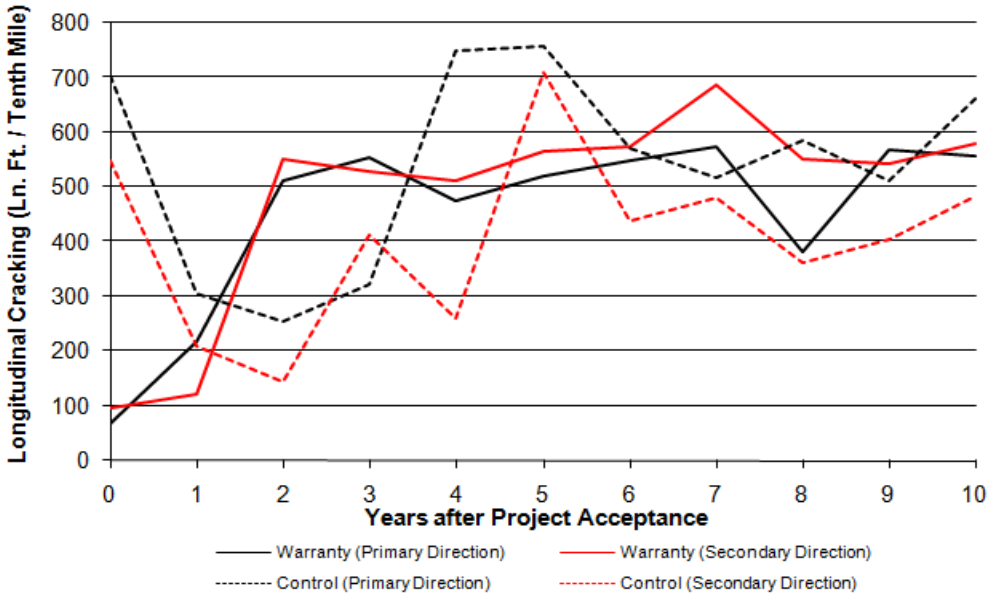

Figure 25. Comparison of the US 36/ I-76 longitudinal cracking performance

Figure 26 reveals that both projects had about the same number of transverse cracks prior to the initial construction. However, the warranty project had somewhat less transverse cracks during this performance period. At the end of this study, the warranty project had an extended life of slightly less than two years. Based on this information, we rounded down and determined that there is about a one year benefit in extended life which is about $20,200 per lane-mile for the warranty project.

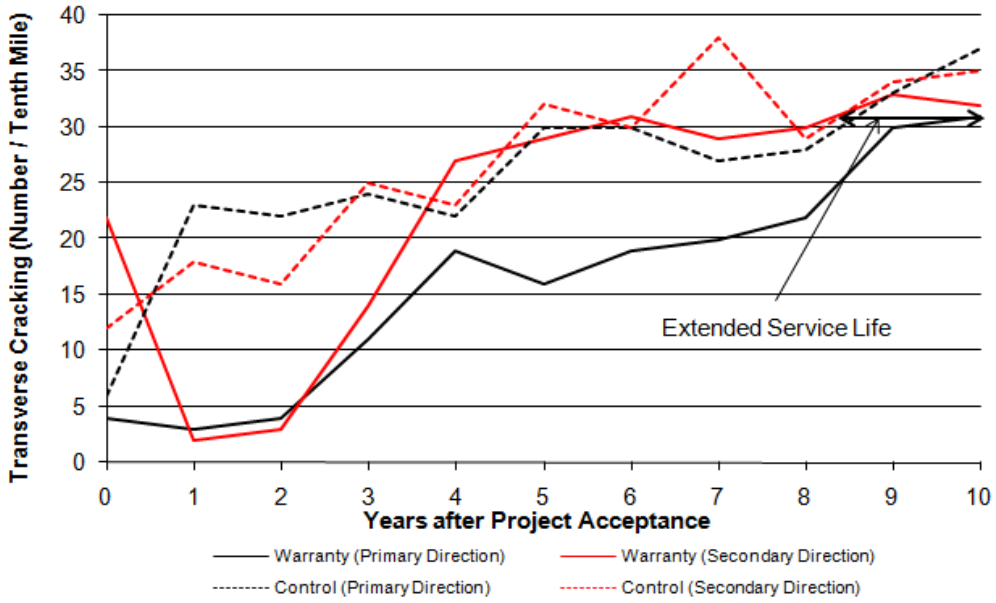

Figure 26. Comparison of the US 36 / I-76 transverse cracking performance

5.4.1 PET Reviews

During the warranty period, three annual evaluations were performed by the PET. All measurements were found to be below the threshold levels of the parameters of the specification.

5.5 Cost-Benefit Analysis

As of January 2012, the net cost on the warranty project is $58,680 per lane-mile (48,826 + 9,854) while the net cost on the control project is $46,970 (42,653 + 4,317) per lane-mile. Since the extended life for rut depth and longitudinal cracking was less than the IRI and transverse cracking, no net benefit in extended life is expected for this warranty project. Since the ratio is 1.25 (58,680/46,970), the cost of a warranty project exceeds the cost of the control project and is not worthwhile.

CHAPTER 6: I-25, NORTH OF PUEBLO

6.1 Project Information

This warranty project is in Pueblo and El Paso Counties on I-25, beginning approximately 14 miles north of Pueblo and extending northerly for 5.3 miles (21.2 lane-miles) from Milepost 114.7 to Milepost 120.0. For reference, the Colorado project number is IM 0251-157 with a sub-account number of 13048.

The control project is in Pueblo County on I-25 north of Pueblo and is adjacent to the warranty project. It extends for approximately 6.4 miles (25.6 lane-miles) from Steel Hollow, Milepost 109.0 to Young Hollow, Milepost 114.7. For reference, the Colorado project number is IM 0251-154 with a sub-account number of 12528. This project was also used as the control project for the warranty project on I-25, South of Fountain.

A comparison of the information from both the warranty and control projects is summarized in Table 5 below. The tonnage information in the following table represents the approximate quantity of HMA used to bid the projects.

Table 5 Comparison summary of the I-25 N. of Pueblo / I-25 Young Hollow project

	Warranty Project	Control Project
Overlay Thickness	4 inches	4 inches
Rehabilitation Strategy	¾-inch milling	2-inch milling
Award Date	February 14, 2000	January 11, 1999
Begin Construction Date	March 29, 2000	March 1, 1999
Project Acceptance Date	December 27, 2000	September 17, 1999
Facility Type	4-lane Interstate	4-lane Interstate
Tonnage	71,905	53,422
Engineer's Estimate, $/ton	$40.00	$35.00
Bid Price, $/ton	$35.20	$32.00
Economy of Scale, $/ton	$28.88	$30.24
Offset to the Unit Price, $/ton	N/A	$1.36
Mix Gradation	S	S
Type of Binder	PG 58-28	AC-20R
Warranty Line Item, L.S.	$50,000	NA
Weigh-In-Motion Station	$58,500	NA
Quality Control Testing	($21,600)	NA
PET Reviews (3 years)	$16,200	NA
10-year Design ESALs	5,372,000	5,372,000
Average Annual Daily Traffic	14,500	14,500
Single Unit Trucks (percent)	4.3	4.3
Combination Trucks (percent)	7.3	7.3

6.2 Initial Construction Cost

Using the information from the previous table, the standardized unit cost of the warranty project HMA is $35.20 per ton which results in a cost of $2,531,056 (35.20 * 71,905). In addition, it cost $50,000 for the warranty line item, $16,200 for the PET reviews during the warranty period and $58,500 to install a weigh-in-motion station. However, it saved $21,600 in quality control testing. This resulted in a cost to CDOT of $124,253 per lane-mile (2,531,056 + 50,000 + 16,200 + 58,500 – 21,600)/21.2 to construct and monitor the warranty project. The cost to construct the control project is $63,939 per lane-mile ((32.00 – 1.36) * 53,422)/25.6.

6.3 Maintenance and User Cost

The cost of CDOT roadway surface maintenance activities is summarized below in Figure 27 for the warranty and control project as collected in MMS. As of January 1, 2012 CDOT has spent a total of $9,164 per lane-mile on the warranty project while spending $8,692 per lane-mile on the control project.

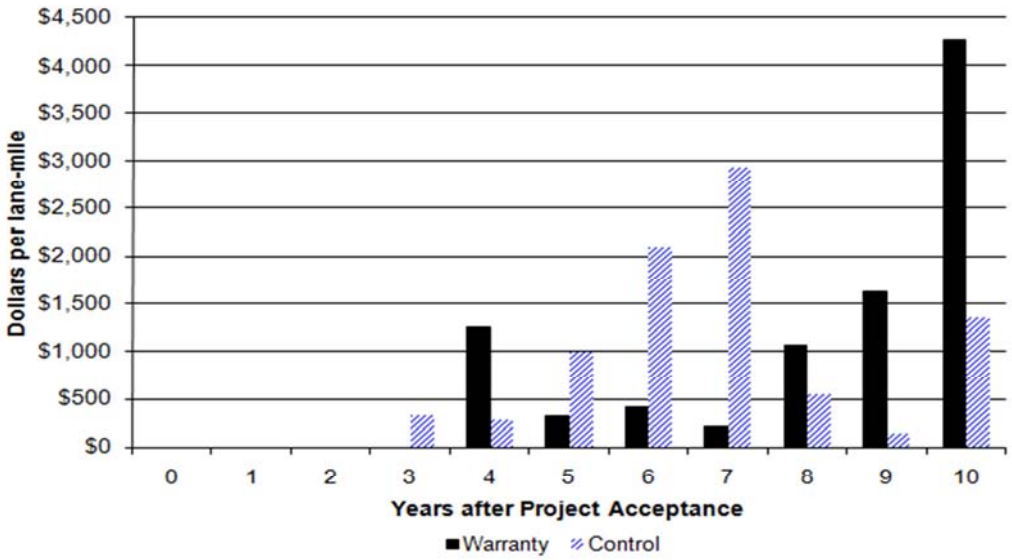

Figure 27. Comparison of I-25 N. of Pueblo / I-25 Young Hollow maintenance cost

6.4 Performance Data

The IRI performance data shown in Figure 28 indicates that both projects are performing well and no difference in IRI could be determined. Based on this information, there is no expected benefit in extended life for the warranty project.

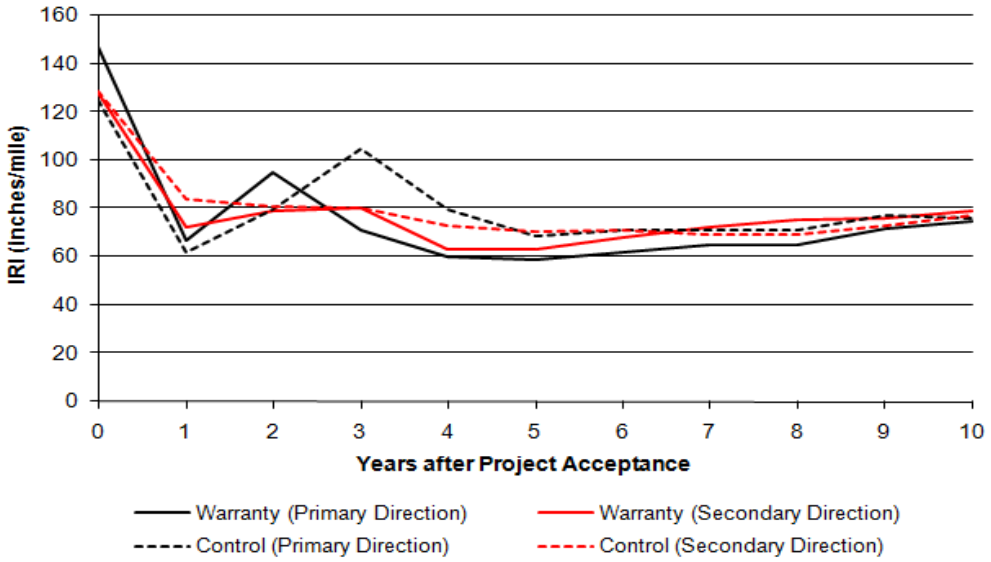

Figure 28. Comparison of I-25 N. of Pueblo / I-25 Young Hollow IRI performance

In the ten years after acceptance, the rut data shown in Figure 29 indicates that the warranty project has slightly greater rut depth than the control project. Based on this information, there is no expected benefit in extended life for the warranty project. The traffic data indicated in Figure 30 shows that the loading on the warranty project was not exceeded during the 3-year warranty period.

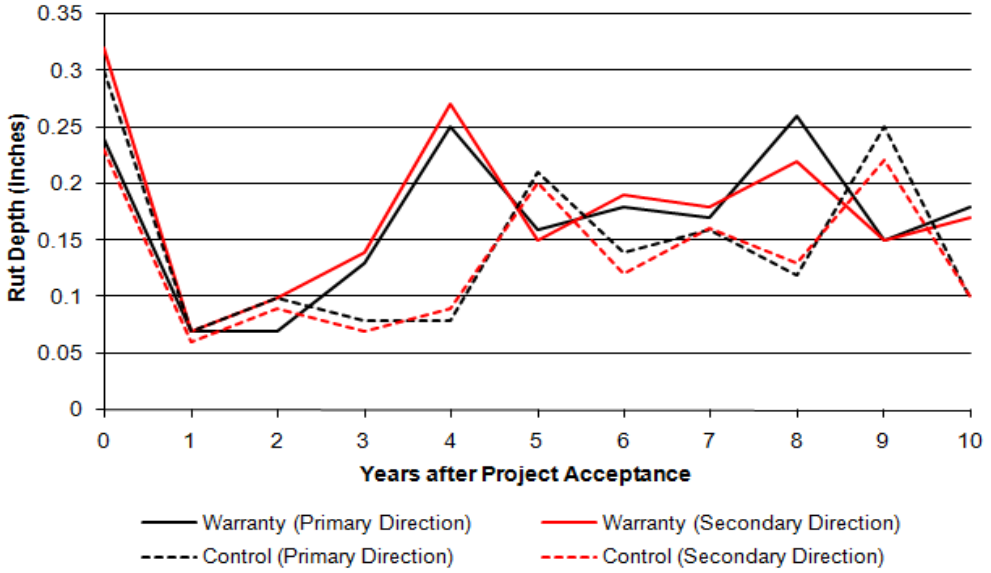

Figure 29. Comparison of I-25 N. of Pueblo / I-25 Young Hollow rut depth performance

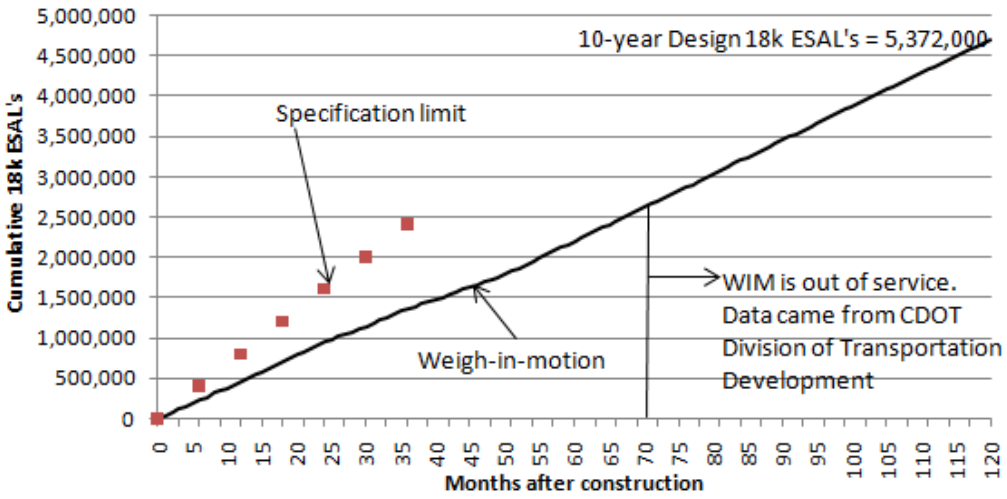

Figure 30. Cumulative weigh-in-motion 18k ESALs on I-25 N. of Pueblo warranty project

The fatigue data is included for information only. It is not a specified distress in the warranty project. Figure 31 indicates that a very small amount of cracking on both projects has re-appeared after 10 years in service. Equal performance is found in both projects.

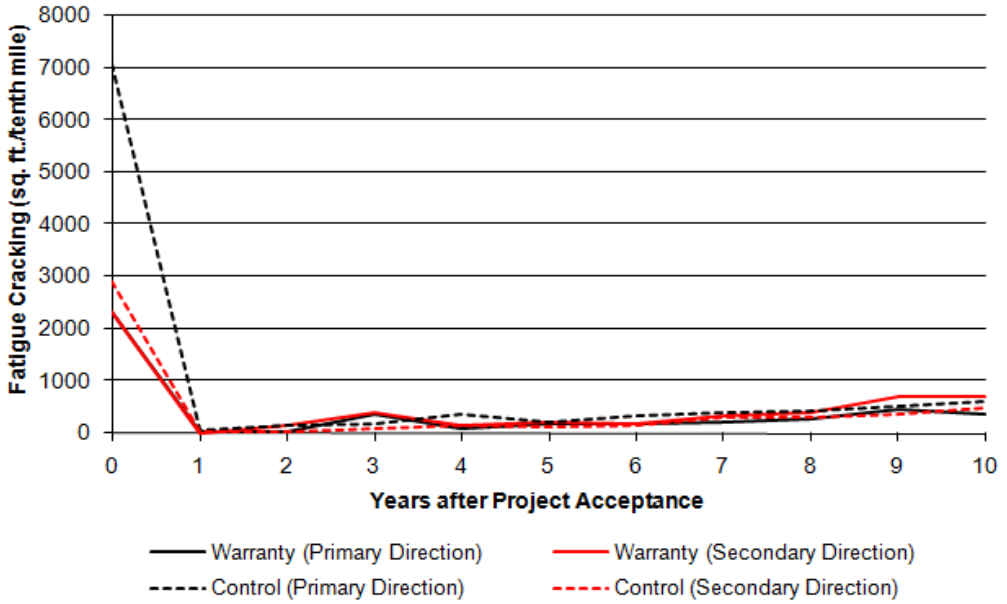

Figure 31. Comparison of I-25 N. of Pueblo / I-25 Young Hollow fatigue cracking performance

The longitudinal cracking data in Figure 32 illustrates that both projects started out with about the same amount of cracking. However, after 10-years of service, the control project is performing better than the warranty project. Therefore, no extended life for the warranty project could be determined.

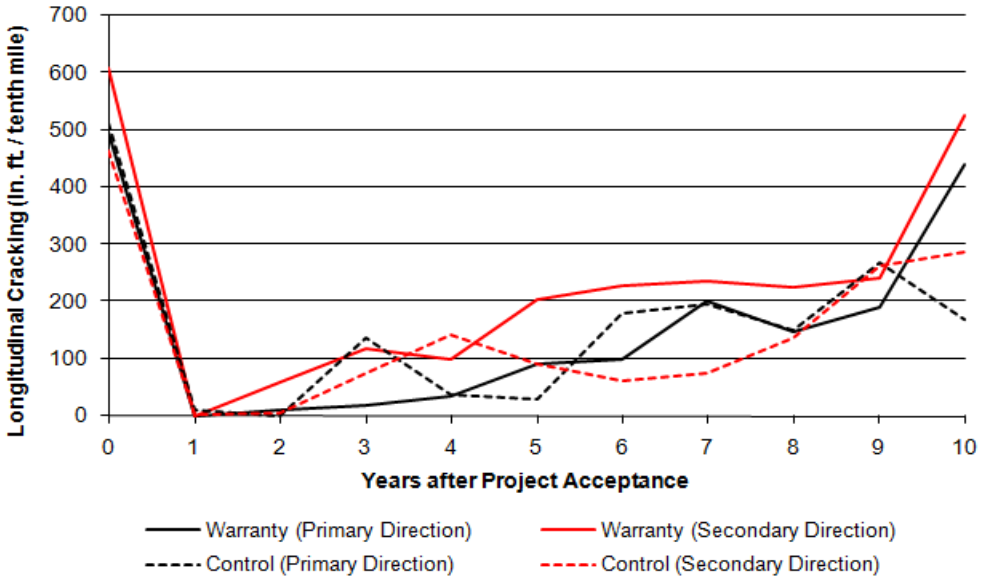

Figure 32. Comparison of I-25 N. of Pueblo / I-25 Young Hollow longitudinal cracking performance

Figure 33 reveals that both projects had about the same number of transverse cracks prior to the initial construction. During this performance period, both projects are performing well. The secondary direction of the control project has the least amount of transverse cracks. This information indicates that there is very little difference between the projects and no benefit in extended life is available for the warranty project.

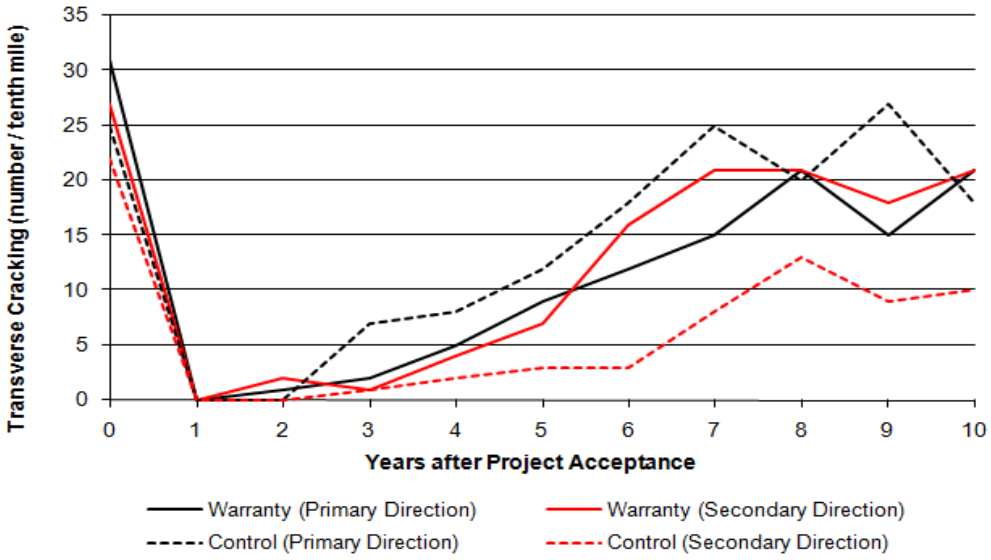

Figure 33. Comparison of I-25 N. of Pueblo / I-25 Young Hollow transverse cracking performance

6.4.1 PET Reviews

During the warranty period, three annual evaluations were performed by the PET. All measurements were found to be below the threshold levels of the parameters of the specification.

6.5 Cost-Benefit Analysis

As of January 2012, the net cost on the warranty project is $133,417 per lane-mile (124,253 + 9,164) while the net cost on the control project is $72,631 per lane-mile (63,939 + 8,692). No net benefit in extended life is expected for this warranty project. Since the ratio is 1.84 (133,417 / 72,631), the cost of a warranty project exceeds the cost of the control project and is not worthwhile.

CHAPTER 7: I-70, EAST OF EAGLE

7.1 Project Information

This warranty project is in Eagle County on I-70 east of the town of Eagle and extends east for approximately 11.9 miles (47.6 lane-miles) from Milepost 147.0 to Milepost 158.9. For reference, the Colorado project number is IM 0702-222 with a sub-account number of 12731.

The control project is in Eagle, Garfield, and Pitkin Counties on State Highway 82 beginning approximately 2 miles north of Carbondale, Milepost 10.4 and extending 12.7 miles southeasterly to Milepost 23.1 with two no work sections at Milepost 10.5 to Milepost 14.0 and Milepost 18.0 to Milepost 20.8. The net project length is 6.4 miles (25.6 lane-miles.) For reference, the Colorado project number is STA 0821-057 with a sub-account number of 13092.

A comparison of the information from both the warranty and control projects is summarized in Table 6 below. The tonnage information in the following table represents the approximate quantity of HMA used to bid the projects.

Table 6 Comparison summary of the I-70 / SH 82 project

	Warranty Project	Control Project
Overlay Thickness	2 inches	2 inches
Rehabilitation Strategy	1-inch leveling course	Milling/Recondition Base/Overlay
Award Date	January 21, 2000	June 27, 2000
Begin Construction Date	May 19, 2000	August 7, 2000
Project Acceptance Date	October 10, 2000	October 12, 2000
Facility Type	4-lane Interstate	4-lane Primary Highway
Tonnage	102,870	40,294
Engineer's Estimate, $/ton	$41.00	$50.55
Bid Price, $/ton	$32.50	$37.85
Economy of Scale, $/ton	$27.25	$30.04
Offset to the Unit Price, $/ton	N/A	$2.79
Mix Gradation	SX	SX
Type of Binder	PG 58-22	PG 64-28
Warranty Line Item, Low Bid	$138,855	NA
Weigh-In-Motion Station	$57,189	NA
Quality Control Testing	($30,900)	NA
PET Reviews (3 years)	$16,200	NA
10-year Design ESALs	4,288,903	1,197,000
Average Annual Daily Traffic	23,700	19,600
Single Unit Trucks (percent)	4.1	3.8
Combination Trucks (percent)	9.4	1.3

7.2 Initial Construction Cost

Using the information from the previous table, the standardized unit cost of the warranty project HMA is $32.50 per ton which results in a cost of $3,343,275 (32.50 * 102,870). In addition, it cost $138,855 for the warranty line item, $16,200 for the PET reviews during the warranty period and $57,189 to install a weigh-in-motion station. However, it saved $30,900 in quality control testing. This resulted in a cost to CDOT of $74,047 per lane-mile (3,343,275 + 138,855 + 16,200 + 57,189 – 30,900)/47.6 to construct and monitor the warranty project. The cost to construct the control project is $55,184 per lane-mile ((37.85 – 2.79) * 40,294)/25.6.

7.3 Maintenance and User Cost

The cost of CDOT roadway surface maintenance activities is summarized below in Figure 34 for the warranty and control project as collected in MMS. As of January 1, 2012 CDOT has spent a total of $4,369 per lane-mile on the warranty project while spending $13,215 per lane-mile on the control project.

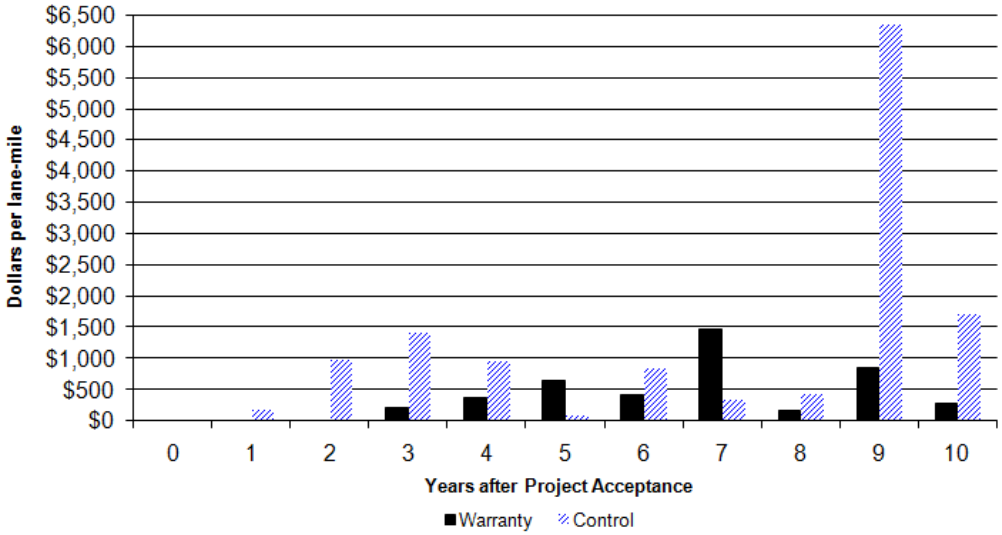

Figure 34. Comparison of the I-70 / SH 82 maintenance cost

7.4 Performance Data:

The IRI performance data shown in Figure 35 indicates that the both projects are performing about the same over the 10-year period. Based on this information, there is no expected benefit in extended life for the warranty project.

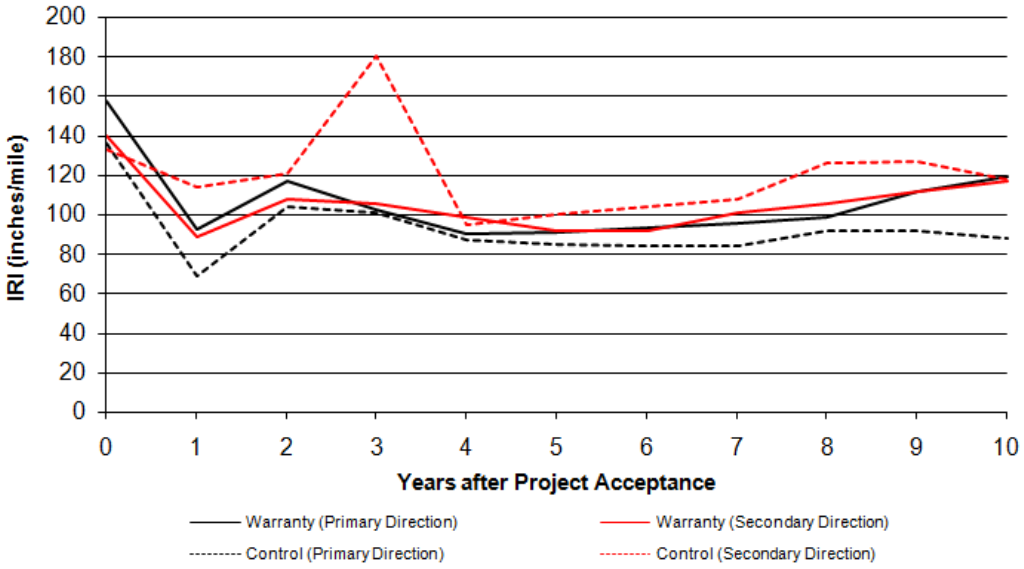

Figure 35. Comparison of the I-70 / SH 82 IRI performance

In the ten years after acceptance, the rut data shown in Figure 36 indicates that the warranty project performed better than the control project and had an extended service life of over four years. Based on this information and rounding down, there is a four year benefit in extended life which is about $80,800 per lane-mile (4 * 20,200) for the warranty project. The traffic data in Figure 37 illustrates that the loading on the warranty project was not exceeded during the 3-year warranty period.

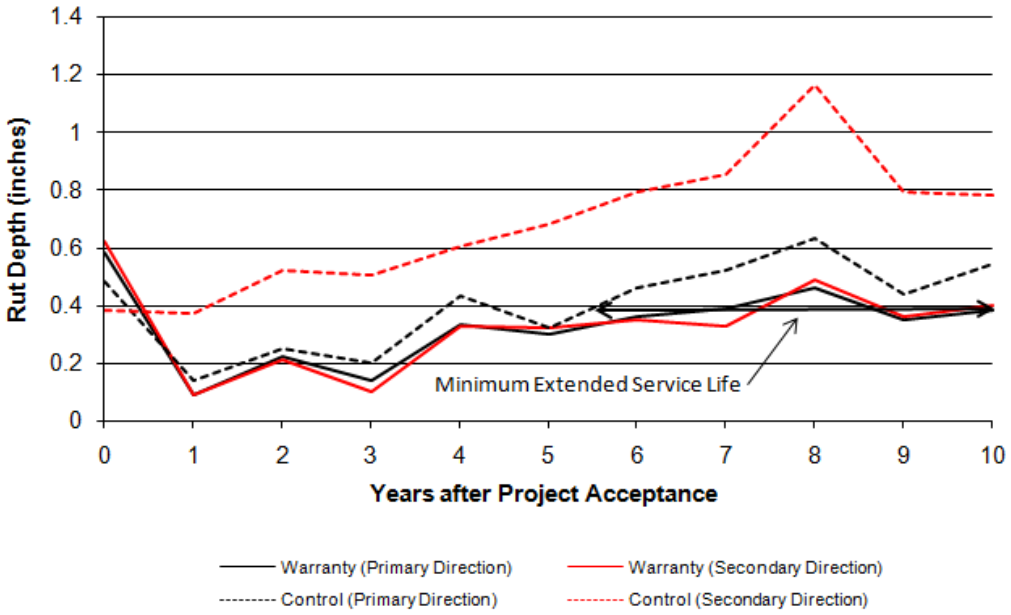

Figure 36. Comparison of the I-70 / SH 82 rut depth performance

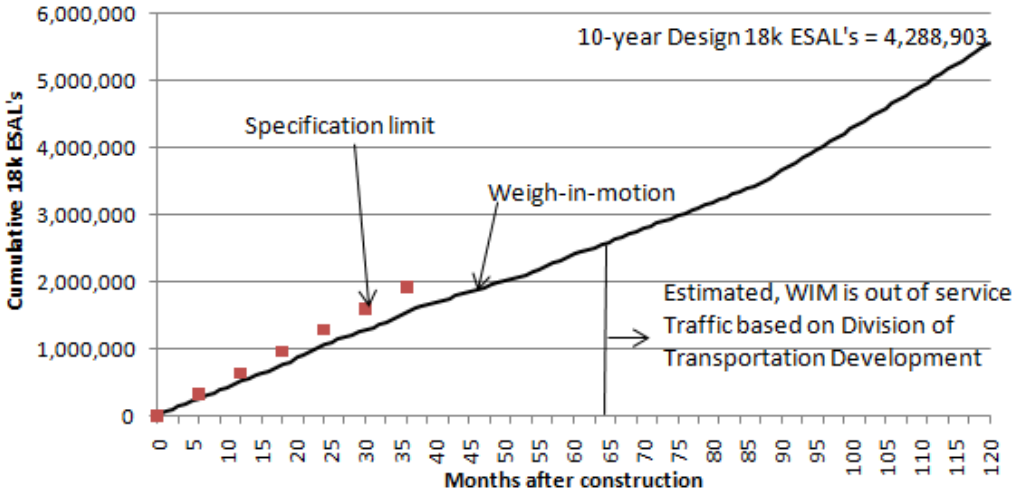

Figure 37. Cumulative weigh-in-motion 18k ESALs on I-70 warranty project

The fatigue data is included for information only. It is not a specified distress in the warranty project. Figure 38 indicates that a very small amount of cracking on both projects has re-appeared after eight years in service. The control project seems to be performing better than the warranty project.

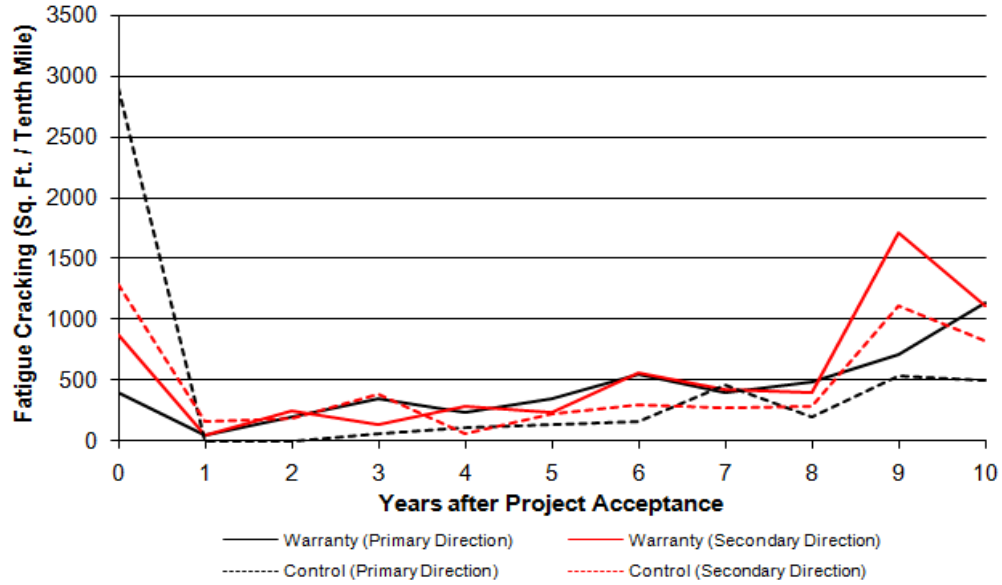

Figure 38. Comparison of the I-70 / SH 82 fatigue cracking performance

The longitudinal cracking data in Figure 39 illustrates that the secondary direction of the warranty project started out with significantly more cracking. The increase in longitudinal cracking over time appears to be about the same and after 10-years of service both projects have about the same amount of cracks. Therefore, no benefit to extending the life on this warranty project could be found.

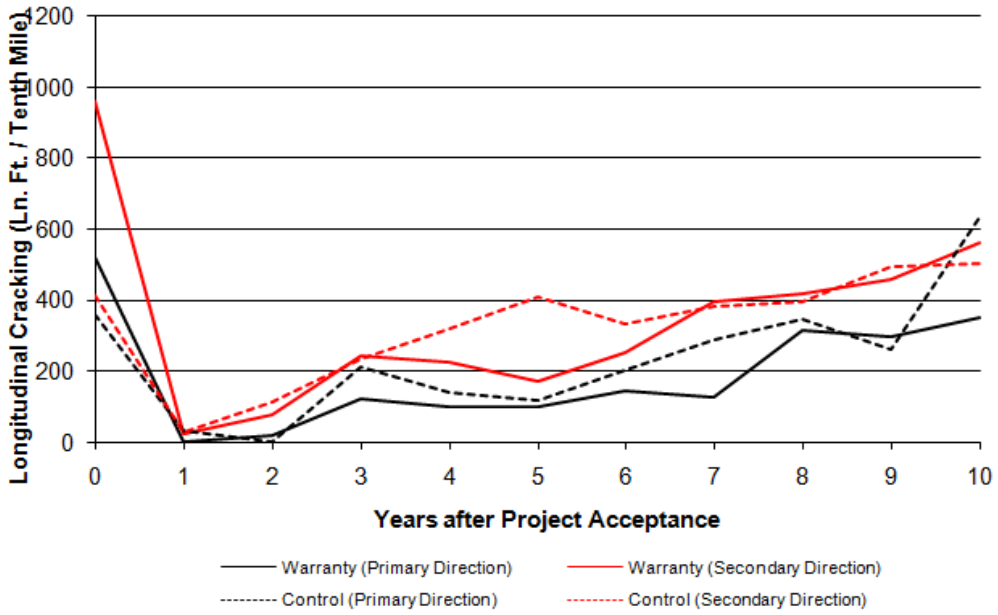

Figure 39. Comparison of the I-70 / SH 82 longitudinal cracking performance

Figure 40 reveals that the warranty project had significantly more transverse cracks prior to the initial construction. During this performance period, both projects are doing well. From this information, the control project is doing better and no benefit in extended life should be given for the warranty project.

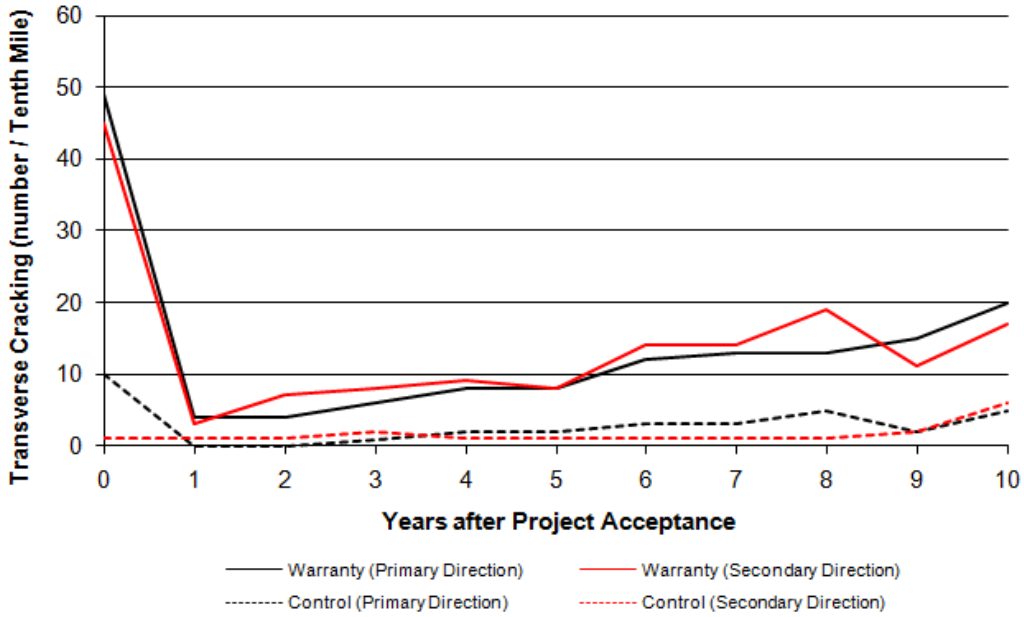

Figure 40. Comparison of I-70 / SH 82 transverse cracking performance

7.4.1 PET Reviews

During the warranty period, three annual evaluations were performed by the PET. At the first evaluation, the only distress that the PET found was low to moderate raveling in the wheel paths. The second evaluation by the PET found the same distress. In the third evaluation, the raveling appeared to be moderate to severe. Due to the subjective process in evaluating the severity of raveling, the PET reviewed nearby projects constructed in the same year as the warranty project. These projects also showed signs of raveling in the wheel paths. Since the PET determined that the raveling was natural to the area, no corrective action was recommended.

7.5 Cost-Benefit Analysis

As of January 2012, the net cost on the warranty project is $78,416 per lane-mile (74,047 + 4,369) while the net cost on the control project is $68,399 per lane-mile (55,184 + 13,215). No net benefit in extended life is expected for this warranty project. Since the ratio is 1.15 (78,416 / 68,399), the cost of a warranty project exceeds the cost of the control project and is not worthwhile.

CHAPTER 8: U.S. HIGHWAY 50, EAST OF KANNAH CREEK

8.1 Project Information

This warranty project is in Mesa and Delta Counties on U.S. 50 east of Kannah Creek and extends southeasterly for approximately 7.3 miles (29.2 lane-miles) from Milepost 46.0 to Milepost 53.3. For reference, the Colorado project number is NH 0501-038 with a sub-account number of 12153. The warranty project was constructed adjacent to the previously constructed control project.

The control project is in Mesa County on U.S. 50 southeast of Whitewater and extends southeasterly for about 4 miles (16.0 lane-miles) from Milepost 42.0 to Milepost 46.0. For reference, the Colorado project number is SP 0501-037 with a sub-account number of 11838.

There was no existing pavement structure prior to the construction projects.

A comparison of the information from both the warranty and control projects is summarized in Table 7 below. The tonnage information in the following table represents the approximate quantity of HMA used to bid the projects.

Table 7 Comparison summary of the US 50 Kannah Creek / US 50 Whitewater project

	Warranty Project	Control Project
HMA Thickness	6-3/4 inches	6-3/4 inches
Rehabilitation Strategy	Reconstruction/Widening	New Construction/Widening
Award Date	November 16, 2000	April 16, 1999
Begin Construction Date	December, 2000	May 10, 1999
Project Acceptance Date	June, 14, 2002	May 9, 2000
Facility Type	4-lane National Highway	4-lane National Highway
Tonnage	60,332	69,408
Engineer's Estimate, $/ton	$39.92	$33.62
Bid Price, $/ton	$29.03	$31.15
Economy of Scale, $/ton	$28.81	$28.39
Offset to the Unit Cost, $/ton	$0.42	N/A
Mix Gradation	SMA	SX
Type of Binder	PG 76-28	PG 70-34
Warranty Line Item	$100,000	NA
Weigh-In-Motion Station	$55,000	NA
Quality Control Testing	($18,300)	NA
PET Reviews (1 required)	$5,400	NA
20-year Design ESALs	3,743,000	3,743,000
Average Annual Daily Traffic	9,900	9,900
Single Unit Trucks (percent)	6.0	6.0
Combination Trucks (percent)	4.8	4.8

8.2 Initial Construction Cost

Using the information from the previous table, the standardized unit cost of the warranty project HMA is $28.61 per ton (29.03 – 0.42) which results in a cost of $1,726,098 (28.61 * 60,332). In addition, it cost $100,000 for the warranty line item, $5,400 for the PET reviews during the warranty period and $55,000 to install a weigh-in-motion station. However, it saved $18,300 in quality control testing. This resulted in a cost to CDOT of $63,979 per lane-mile (1,726,098 + 100,000 + 5,400 + 55,000 – 18,300)/29.2 to construct and monitor the warranty project. The cost to construct the control project is $135,129 per lane-mile (31.15 * 69,408)/16.

8.3 Maintenance and User Cost

The cost of CDOT roadway surface maintenance activities is summarized below in Figure 41 for the warranty and control project as collected in MMS. Based on this data, CDOT forces did some crack sealing in the year following the end of the warranty period. Also, they did some crack sealing on the control project in years five and ten. As of January 1, 2012 CDOT has spent a total of $4,535 per lane-mile on the warranty project while spending $4,924 per lane-mile on the control project.

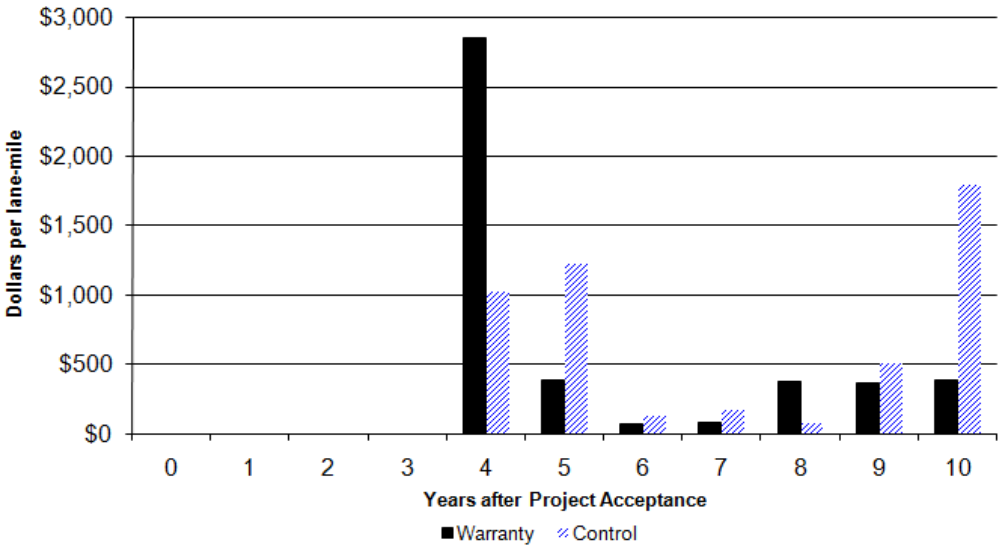

Figure 41. Comparison of the US 50 Kannah Creek / US 50 Whitewater maintenance cost

8.4 Performance Data

The IRI performance data shown in Figure 42 indicates that the control project has slightly less than the warranty project. Based on this information, there is no expected benefit in extended life for the warranty project.

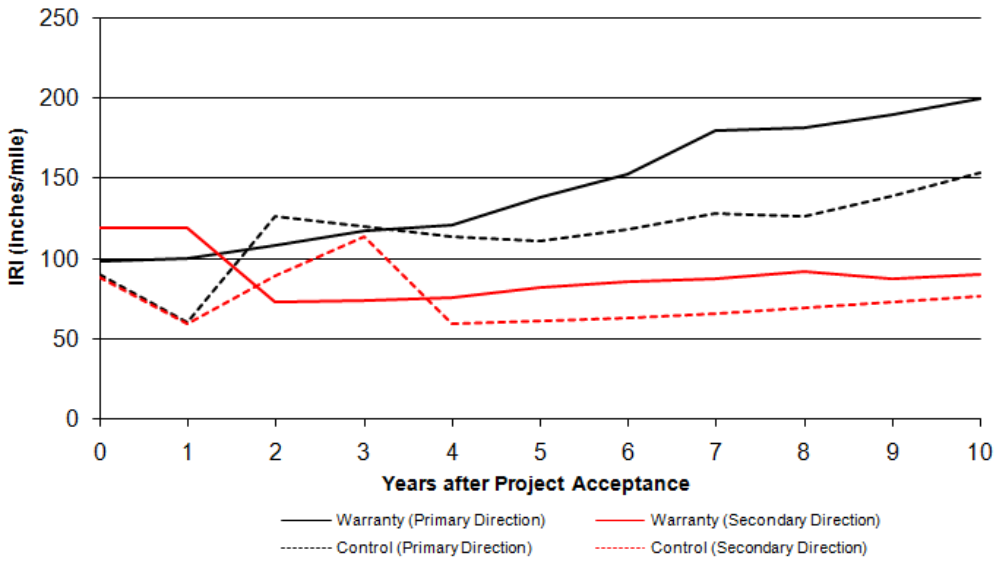

Figure 42. Comparison of the US 50 Kannah Creek / US 50 Whitewater IRI performance

In the ten years after acceptance, the rut data shown in Figure 43 indicates that the warranty project had much more rutting as compared to the control project. Since the control project has less rutting over the performance period, there is no extended life for the warranty project. The traffic data indicated in Figure 44 shows that the loading on the warranty project was not exceeded during the 3-year warranty period.

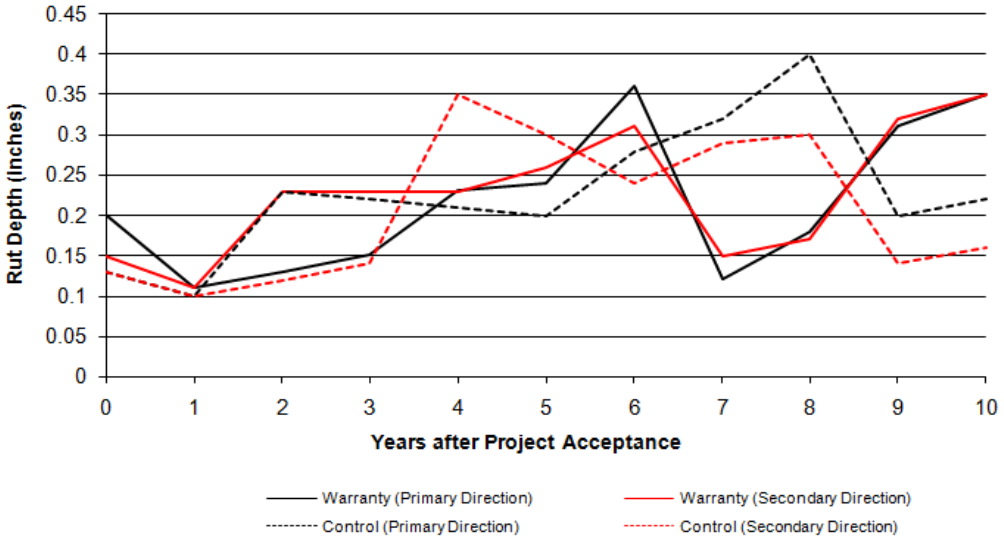

Figure 43. Comparison of the US 50 Kannah Creek / US 50 Whitewater rut depth performance

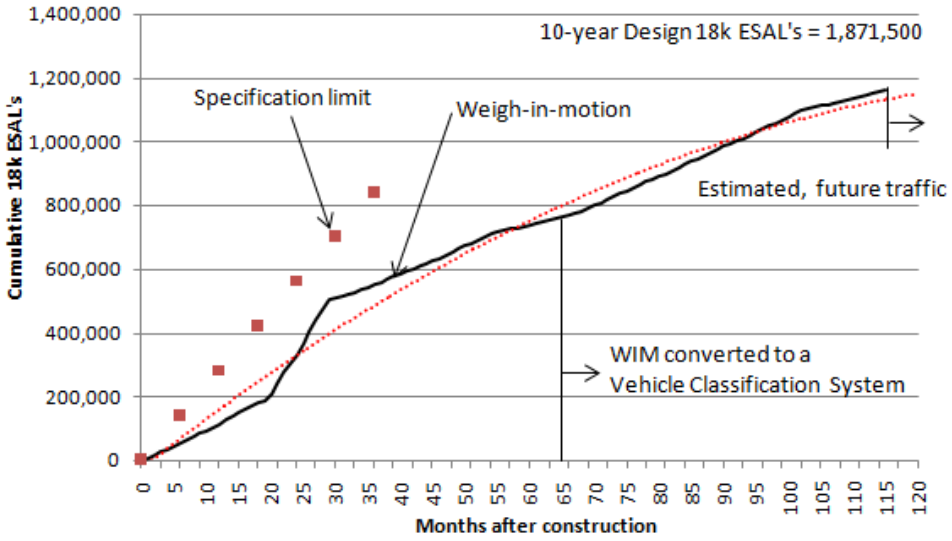

Figure 44. Cumulative weigh-in-motion 18k ESALs on US 50 warranty project

The fatigue data is included for information only. It is not a specified distress in the warranty project. Figure 45 indicates that the primary direction on both projects is performing poorly. While the secondary direction of the control project is doing well, the same direction on the warranty project is doing badly.

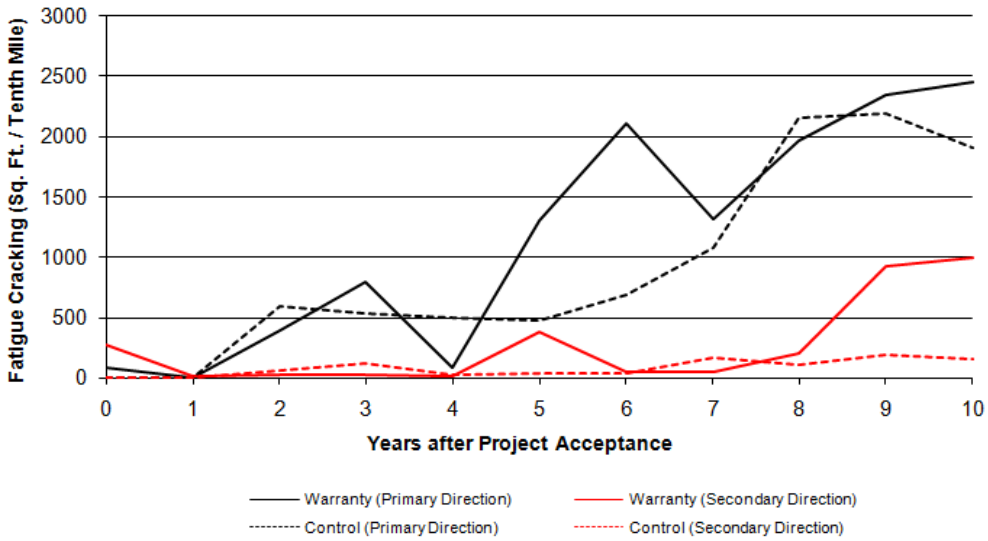

Figure 45. Comparison of the US 50 Kannah Creek / US 50 Whitewater fatigue cracking performance

The longitudinal cracking data in Figure 46 illustrates that the warranty project is somewhat better than the control project at the end of this analysis. Since the extended life of the warranty is less than one year, no benefit is given to extending the life on this warranty project.

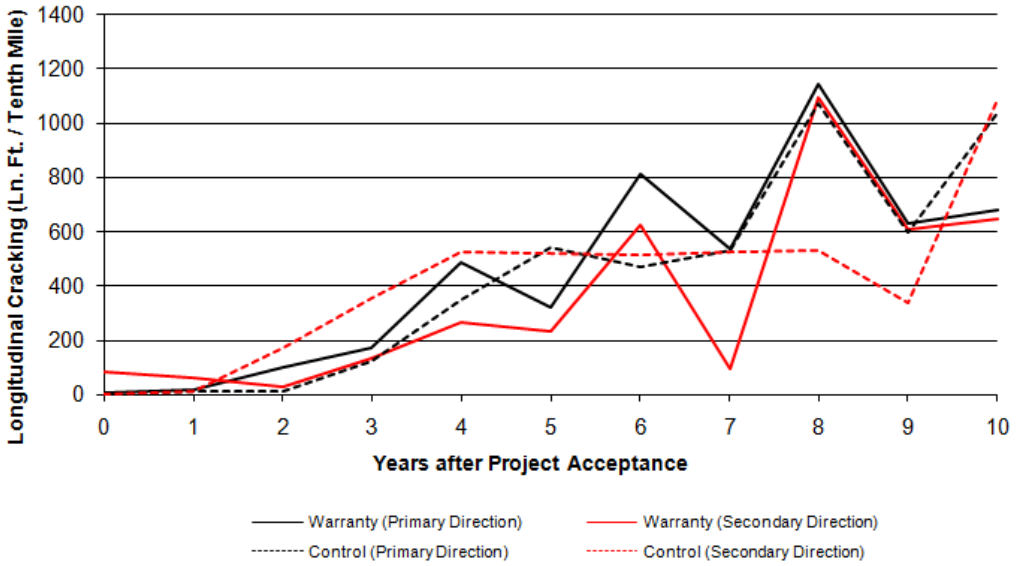

Figure 46. Comparison of the US 50 Kannah Creek / US 50 Whitewater longitudinal cracking performance

Figure 47 reveals that the secondary direction of the warranty project had significantly more transverse cracks prior to the initial construction. During this performance period, the control project is doing better than the warranty project. From this information, no benefit in extended life should be given for the warranty project.

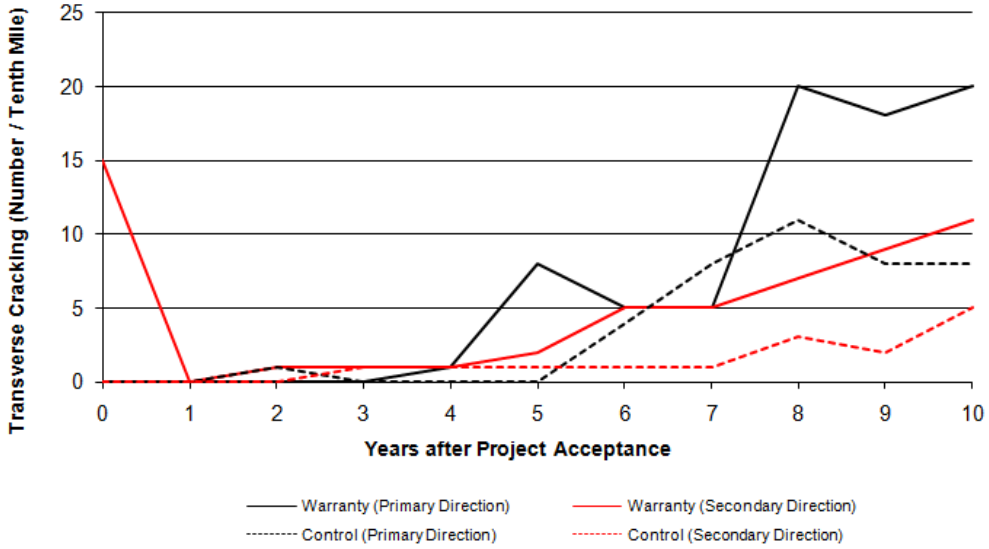

Figure 47. Comparison of US 50 Kannah Creek / US 50 Whitewater transverse cracking performance

8.4.1 PET Reviews

During the warranty period, only one evaluation was required to be performed by the PET. All measurements were found to be below the threshold levels of the parameters of the specification.

8.5 Cost-Benefit Analysis

As of January 2012, the net cost on the warranty project is $68,514 per lane-mile (63,979 + 4,535) while the net cost on the control project is $140,053 per lane-mile (135,129 + 4,924). From these figures, no net benefit in extended life is expected for this warranty project. Since the ratio is 0.49 (68,514 / 140,053), the cost of a warranty project is significantly less than the adjacent control project and is beneficial.

CHAPTER 9: S.H. 63, SOUTH OF I-76 INTERCHANGE

9.1 Project Information

This warranty project is in Logan County on S.H. 63 beginning approximately ¼ mile south of the intersection of I-76 for 8.1 miles (16.2 lane-miles) and extending southerly from Milepost 45.1 to Milepost 53.2. For reference, the Colorado project number is STA 0631-008 with a sub-account number of 13788.

The control project is in Weld County on S.H. 71 and extends northerly for 18.9 miles (37.8 lane-miles) from Milepost 214.0 to the Nebraska State Line at Milepost 232.9. For reference, the Colorado project number is STA 071A-014 with a sub-account number of 13906.

A comparison of the information from both the warranty and control projects is summarized in Table 8 below. The tonnage information in the following table represents the approximate quantity of HMA used to bid the projects.

Table 8 Comparison summary of the SH 63 / SH 71 project

	Warranty Project	Control Project
Overlay Thickness	4 inches	4 inches
Rehabilitation Strategy	Full Depth Reclamation	Full Depth Reclamation
Award Date	May 7, 2002	May 7, 2002
Begin Construction Date	June 24, 2002	October 21, 2002
Project Acceptance Date	November 13, 2002	November 14, 2003
Facility Type	2-lane State Highway	2-lane State Highway
Tonnage	28,234	79,140
Engineer's Estimate, $/ton	$35.00	$37.00
Bid Price, $/ton	$39.50	$37.50
Economy of Scale, $/ton	$27.41	$22.53
Offset to the Unit Price, $/ton	$4.88	N/A
Mix Gradation	S	S
Type of Binder	PG 58-28	PG 58-34
Warranty Line Item	$39,000	NA
Weigh-In-Motion Station	$58,800	NA
Quality Control Testing	($8,700)	NA
PET Reviews (1 required)	$5,400	NA
20-year Design ESALs	554,000	1,290,348
Average Annual Daily Traffic	670	770
Single Unit Trucks (percent)	4.5	9.1
Combination Trucks (percent)	6.0	30.0

9.2 Initial Construction Cost

Using the information from the previous table, the standardized unit cost of the warranty project HMA is $34.62 per ton (39.5 – 4.88) which results in a cost of $977,461 (34.62 * 28,234). In addition, it cost $39,000 for the warranty line item, $5,400 for the PET reviews during the warranty period and $58,800 to install a weigh-in-motion station. However, it saved $8,700 in quality control testing. This resulted in a cost to CDOT of $66,170 per lane-mile (977,461 + 39,000 + 5,400 + 58,800 – 8,700)/16.2 to construct and monitor the warranty project. The cost to construct the control project is $79,140 per lane-mile (37.50 * 79,140)/37.5.

9.3 Maintenance and User Cost

The cost of CDOT roadway surface maintenance activities is summarized below in Figure 48 for the warranty and control project as collected in MMS. As of January 1, 2012 CDOT has spent a total of $9,397per lane-mile on the warranty project while spending $21,872 per lane-mile on the control project. CDOT forces did crack sealing on the control project in the fourth year after construction.

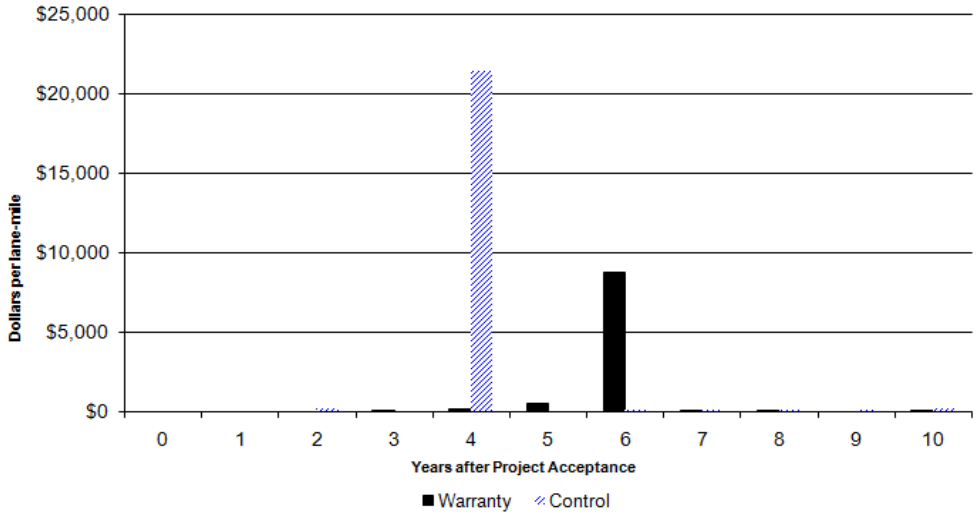

Figure 48. Comparison of the SH 63 / SH 71 maintenance cost

9.4 Performance Data

During the design life, the IRI performance data shown in Figure 49 indicates that both projects are performing well. Therefore, no benefit in extended life for the warranty project is expected.

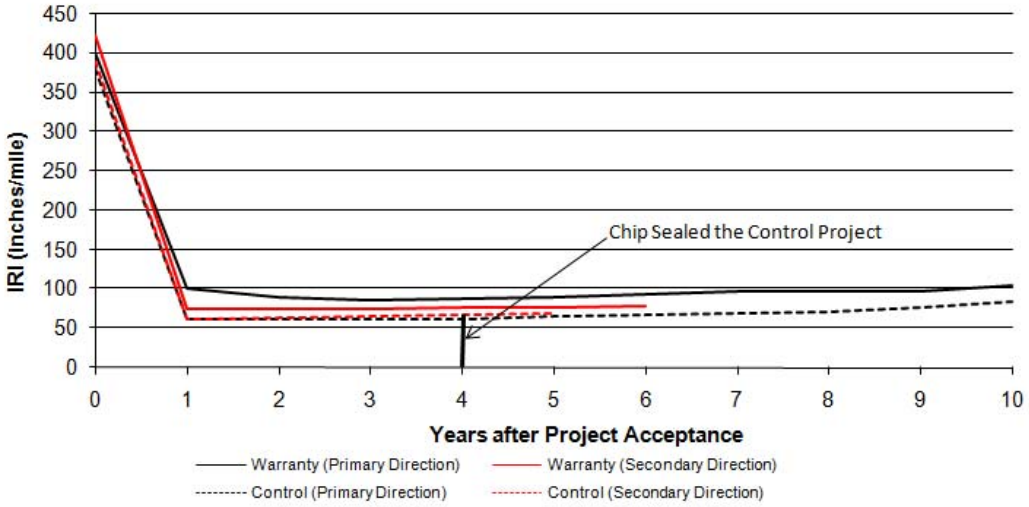

Figure 49. Comparison of the SH 63 / SH 71 IRI performance

While the primary direction of the warranty project is doing well, the rut data shown in Figure 50 indicates that the secondary direction is performing poorly. It is difficult to determine any extended life for the warranty project. Therefore, no benefit is given. The traffic data in Figure 51 shows that the loading on the warranty project was not exceeded during the 3-year warranty period.

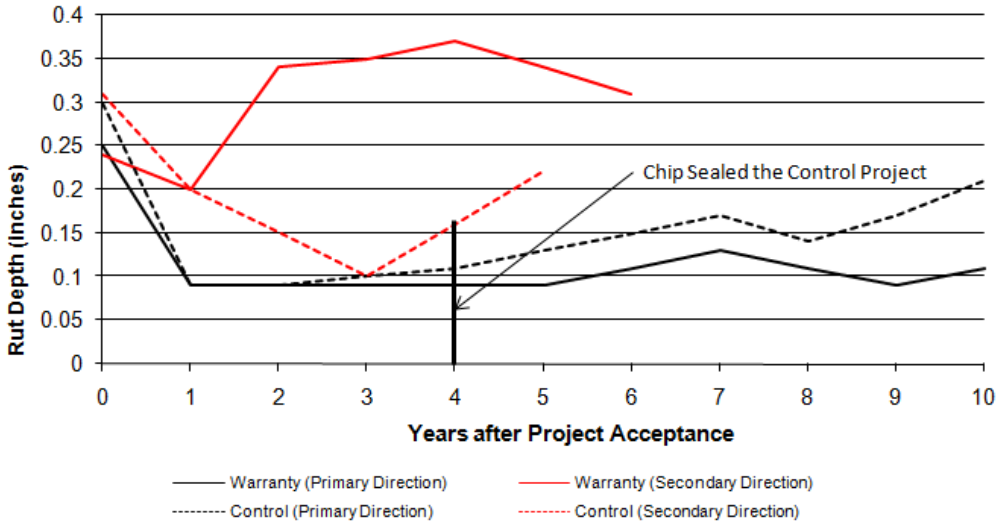

Figure 50. Comparison of the SH 63 / SH 71 rut depth performance

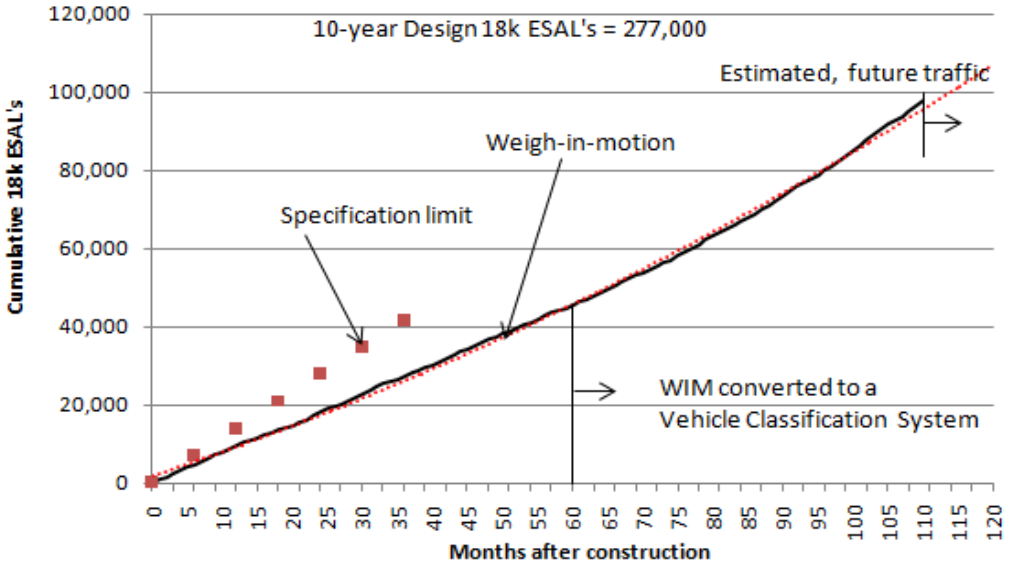

Figure 51. Cumulative weigh-in-motion 18k ESALs on SH 63 warranty project

The fatigue data is included for information only. It is not a specified distress in the warranty project. Figure 52 indicates that the control project started out with significantly more fatigue cracking in the primary direction. At the end of the performance period, the warranty project is performing poorly.

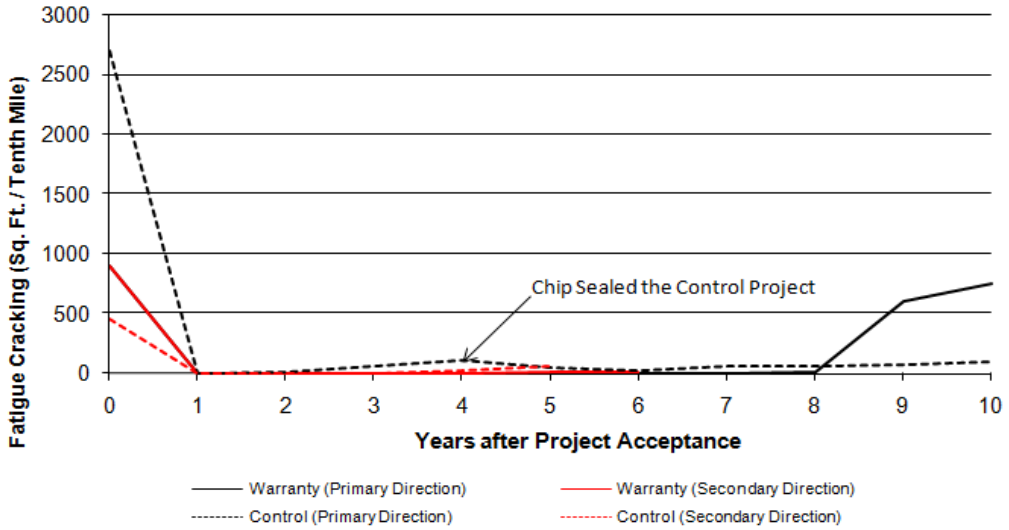

Figure 52. Comparison of the SH 63 / SH 71 fatigue cracking performance

The longitudinal cracking data in Figure 53 illustrates that both projects started with approximately the same amount of cracks. However, after 10 years of service, no difference can be seen between the projects and no benefit is given to extending the life on this warranty project.

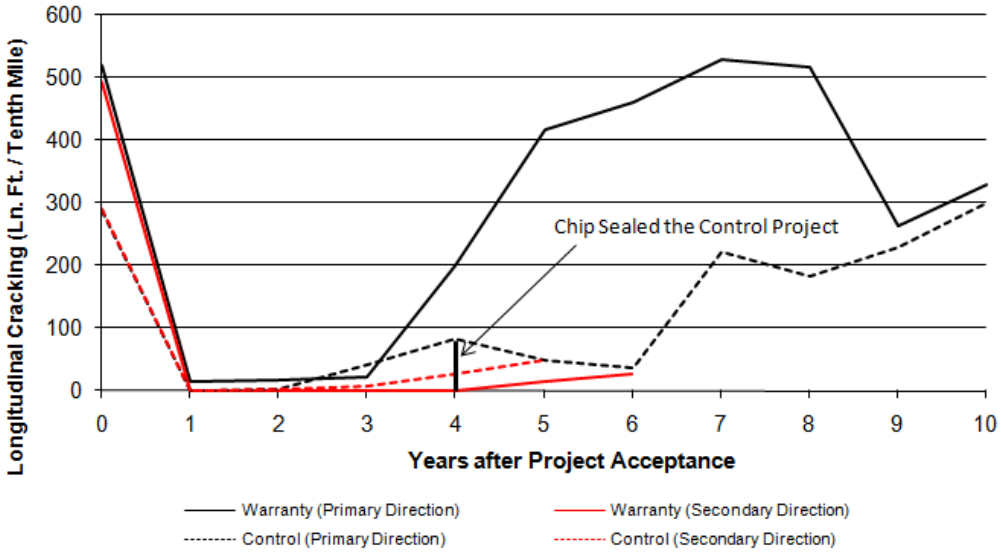

Figure 53. Comparison of the SH 63 / SH 71 longitudinal cracking performance

Figure 54 reveals that there is very little difference between the control and warranty projects. From this information, no benefit in extended life can be determined for the warranty project.

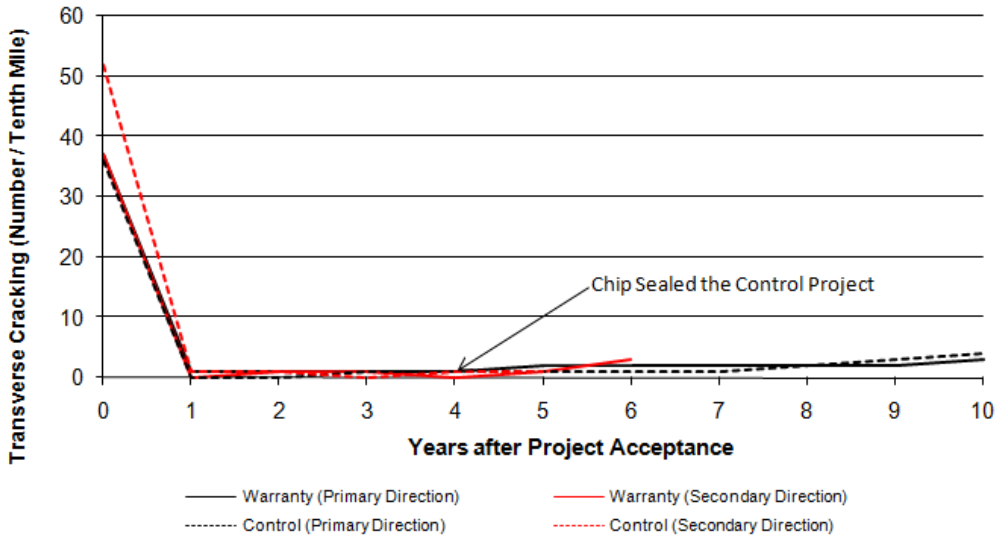

Figure 54. Comparison of SH 63 / SH 71 transverse cracking performance

9.4.1 PET Reviews

During the warranty period, only one evaluation was required to be performed by the PET. All measurements were found to be below the threshold levels of the parameters of the specification.

9.5 Cost-Benefit Analysis

As of January 2012, the net cost on the warranty project is $75,567 per lane-mile (66,707 + 9,397) while the net cost on the control project is $101,012 per lane-mile (79,140 + 21,872). At this time, no net benefit in extended life is expected for this warranty project. Since the ratio is 0.75 (75,567 / 101,012), the cost of a warranty project is less than the control project and is beneficial.

CHAPTER 10: I-25, RAY NIXON - SOUTH

10.1 Project Information

This warranty project is in El Paso County on I-25 beginning approximately15 miles south of Colorado Springs and extending northerly for 4.2 miles (16.8 lane-miles) from Milepost 120.0 to Milepost 124.2. For reference, the Colorado project number is IM 0252-346 with a sub-account number of 13449.

The control project is in Huerfano County on I-25 and extends north of Walsenburg for 7 miles (28 lane-miles) from Milepost 52.0 to Milepost 59.0. For reference, the Colorado project number is IM 0251-159 with a sub-account number of 13931.

A comparison of the information from both the warranty and control projects is summarized in Table 9 below. The tonnage information in the following table represents the approximate quantity of HMA used to bid the projects.

Table 9 Comparison summary of the I-25 Ray Nixon / I-25 Walsenburg project

	Warranty Project	Control Project
Overlay Thickness	4 inches	4 inches
Rehabilitation Strategy	2-inch milling	4-inch milling
Award Date	March 1, 2002	February 13, 2002
Begin Construction Date	April 29, 2002	April 22, 2002
Project Acceptance Date	December 11, 2002	August 27, 2002
Facility Type	4-lane Interstate	4-lane Interstate
Tonnage	59,035	63,299
Engineer's Estimate, $/ton	$32.00	$40.00
Bid Price, $/ton	$28.95	$30.43
Economy of Scale, $/ton	$29.78	$29.46
Offset to the Unit Price, $/ton	$0.32	N/A
Mix Gradation	S	S
Type of Binder	PG 58-28	PG 64-28
Warranty Line Item	$52,500	NA
Weigh-In-Motion Station	Previously Installed	NA
Quality Control Testing	($18,000)	NA
PET Reviews (1 required)	$5,400	NA
Design ESALs	11,906,00 (20-Year)	2,905,254 (10-year)
Average Annual Daily Traffic	17,300	11,700
Single Unit Trucks (percent)	4.6	4.3
Combination Trucks (percent)	7.6	15.0

10.2 Initial Construction Cost

Using the information from the previous table, the standardized unit cost of the warranty project HMA is $28.63 per ton (28.95 – 0.32) which results in a cost of $1,690,172 (28.63 * 59,035). In addition, it cost $52,500 for the warranty line item and $5,400 for the PET reviews during the warranty period. The weigh-in-motion station was previously installed on an adjacent warranty project. This warranty project saved $18,000 in quality control testing. This resulted in a cost to CDOT of $102,980 per lane-mile (1,690,172 + 52,500 + 5,400 – 18,000)/16.8 to construct and monitor the warranty project. The cost to construct the control project is $68,792 per lane-mile (30.43 * 63,299)/28.

10.3 Maintenance and User Cost

The cost of CDOT roadway surface maintenance activities is summarized below in Figure 55 for the warranty and control project as collected in MMS. As of January 1, 2012 CDOT has spent a total of $5,140 per lane-mile on the warranty project while spending $3,241 per lane-mile on the control project.

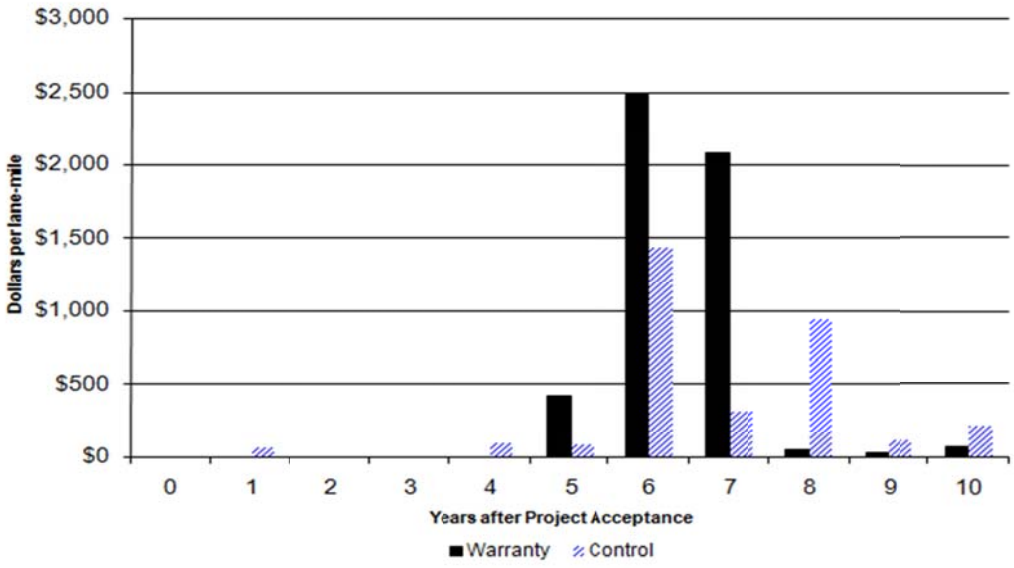

Figure 55. Comparison of the I-25 Ray Nixon / I-25 Walsenburg maintenance cost

10.4 Performance Data

The IRI performance data shown in Figure 56 indicates that there is very little difference between the comparison projects. Both projects are performing well over the service life. Based on this information, no benefit in extended life for the warranty project is expected.

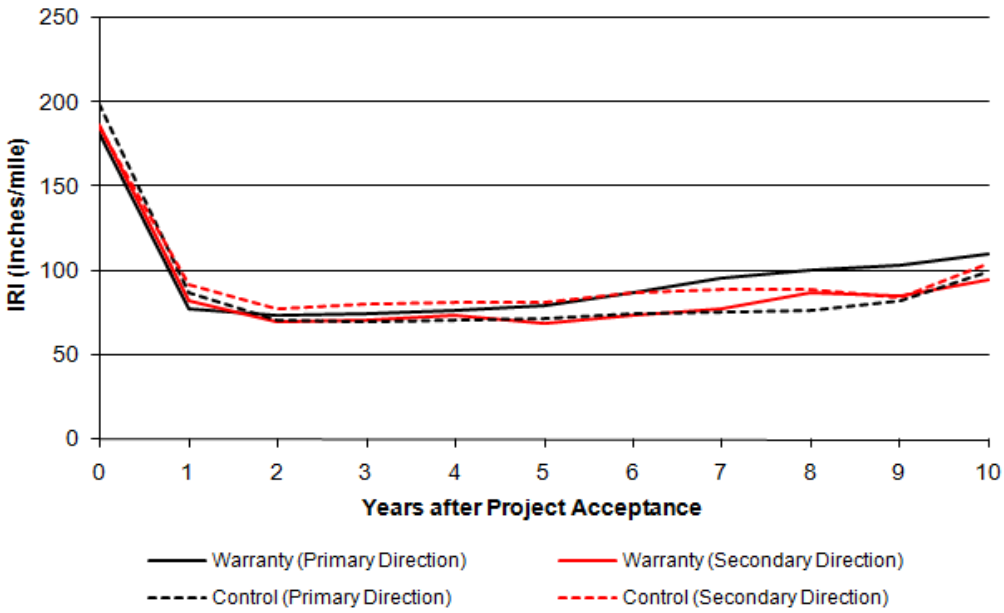

Figure 56. Comparison of the I-25 Ray Nixon / I-25 Walsenburg IRI performance

In the ten years after acceptance, the rut data shown in Figure 57 indicates that both projects are performing about the same. The primary direction of the warranty project has slightly deeper ruts than the secondary direction and both directions of the control project. Based on this information, there is no expected benefit in extended life for the warranty project. The traffic data illustrated in Figure 58 shows that the loading on the warranty project was not exceeded during the 3-year warranty period.

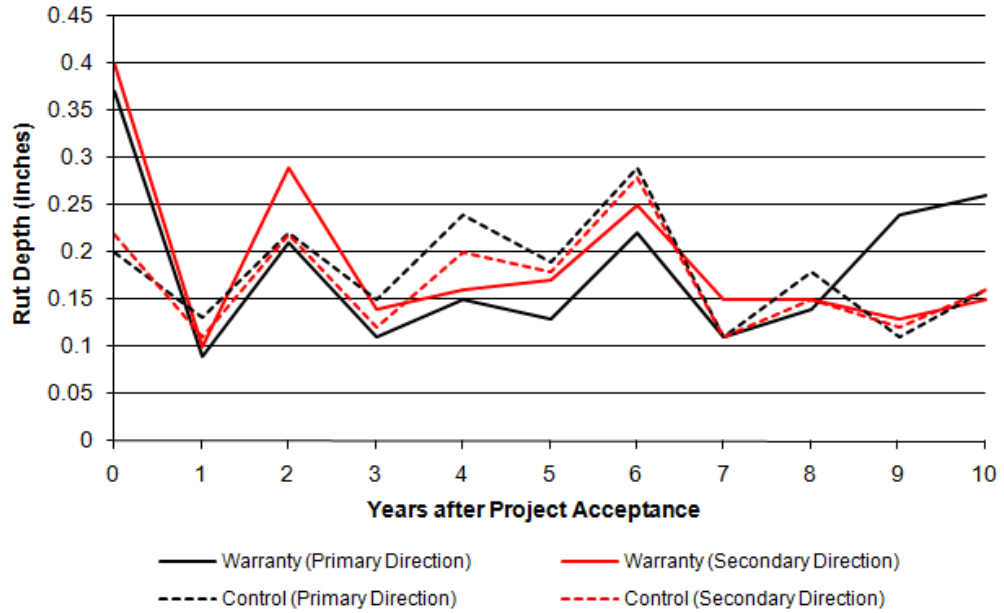

Figure 57. Comparison of the I-25 Ray Nixon / I-25 Walsenburg rut depth performance

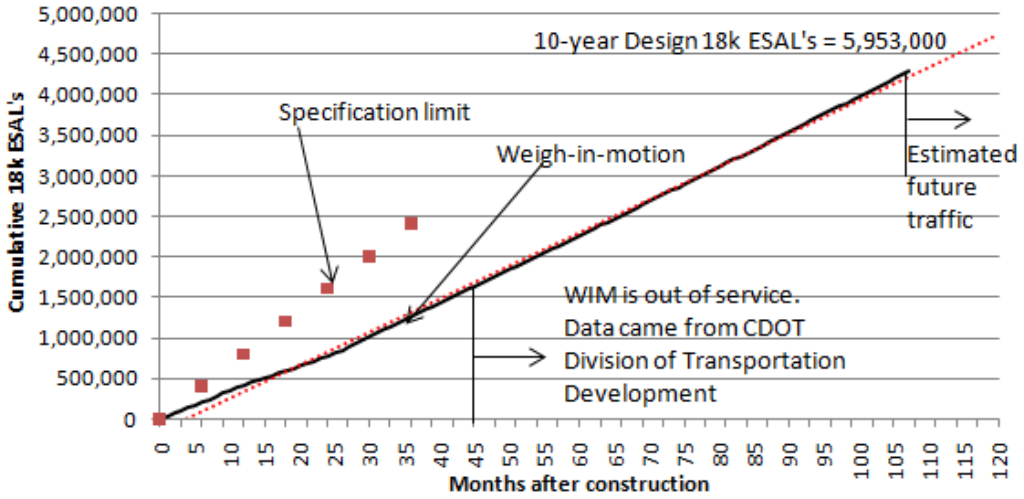

Figure 58. Cumulative weigh-in-motion 18k ESALs on I-25 Ray Nixon warranty project

The fatigue data is included for information only. It is not a specified distress in the warranty project. Figure 59 indicates that both projects started with approximately the same amount of fatigue cracking. However, at the end of the performance period, the secondary direction of the warranty project is performing poorly.

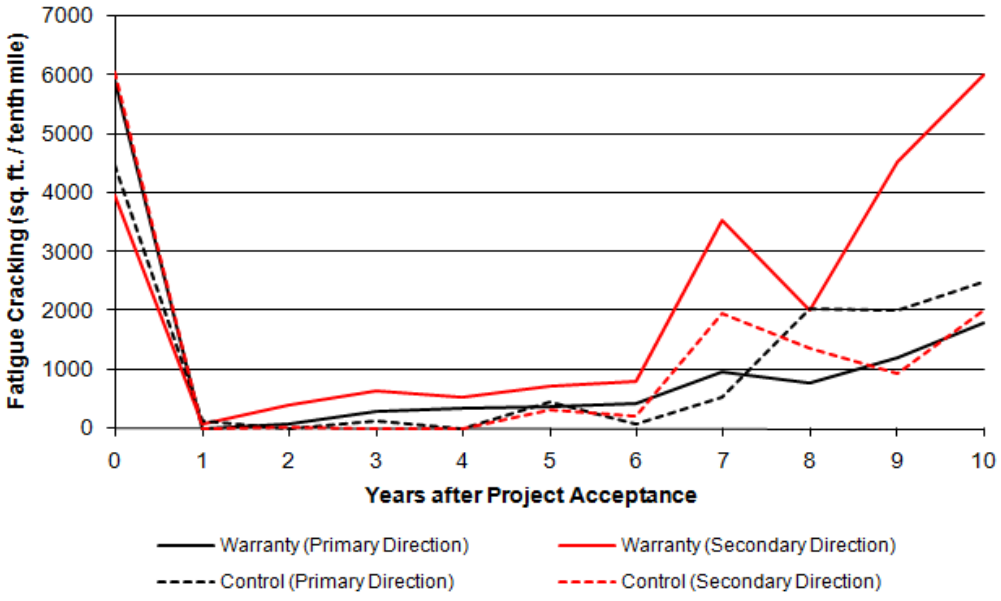

Figure 59. Comparison of the I-25 Ray Nixon / I-25 Walsenburg fatigue cracking performance

The longitudinal cracking data in Figure 60 illustrates that warranty project started with slightly less cracks and the amount of cracking slowly increased over the 10 year performance period. However, the control project increased at a much faster rate. After 10 years of service, about five

years of benefit can be seen between the projects. This extended life is $101,000 per lane mile (5 * 20,200) on this warranty project.

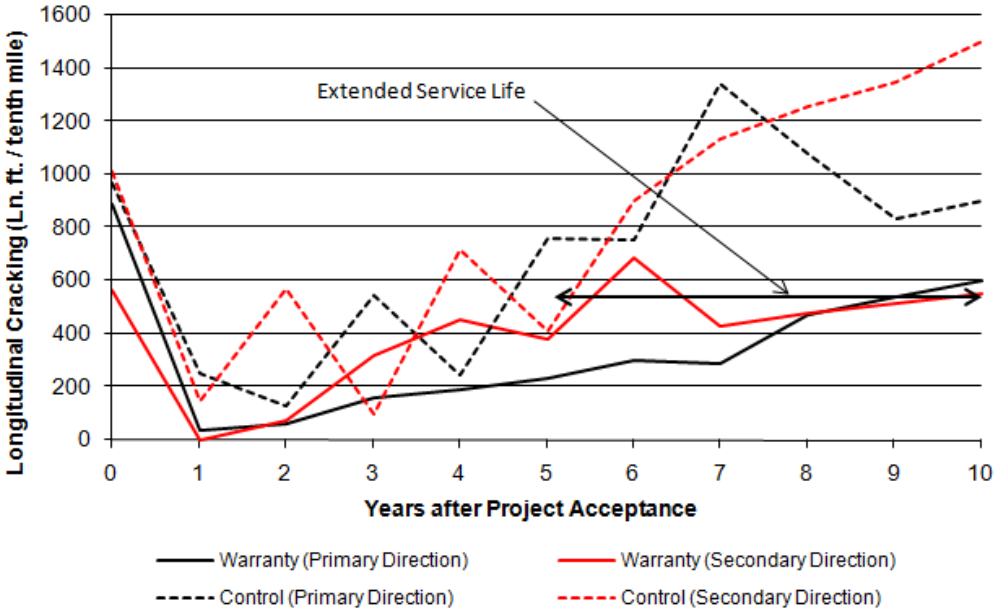

Figure 60. Comparison of the I-25 Ray Nixon / I-25 Walsenburg longitudinal cracking performance

Figure 61 reveals that both projects started with approximately the same amount of cracks. However, after 10 years of service, the control project has significantly less cracks. From this information, no benefit in extended life can be determined for the warranty project.

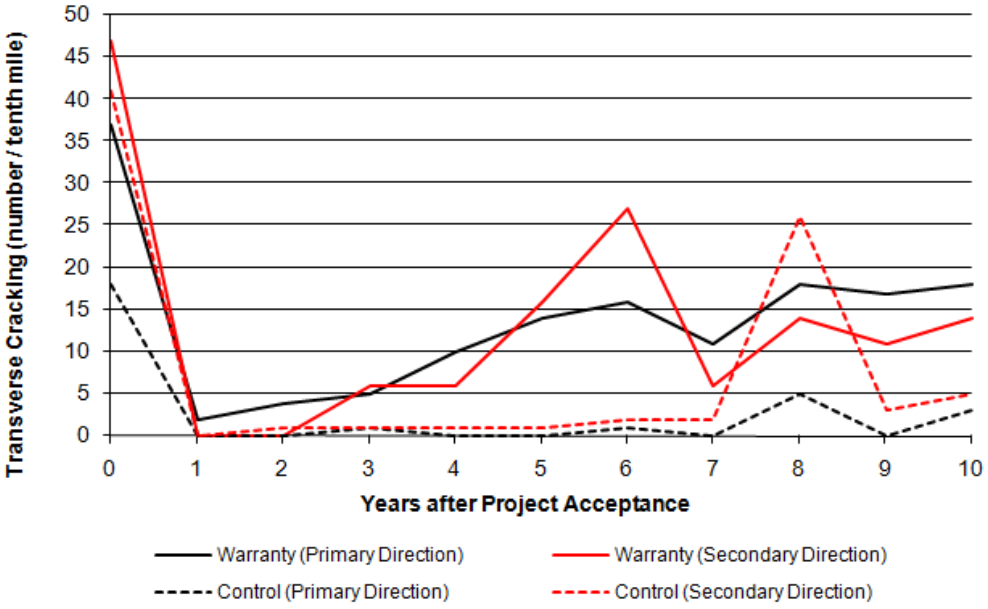

Figure 61. Comparison of I-25 Ray Nixon / I-25 Walsenburg transverse cracking performance

10.4.1 PET Reviews

During the warranty period, only one evaluation was required to be performed by the PET. All measurements were found to be below the threshold levels of the parameters of the specification.

10.5 Cost-Benefit Analysis

As of January 2012, the net cost on the warranty project is $108,120 per lane-mile (102,980 + 5,140) while the net cost on the control project is $72,033 per lane-mile (68,792 + 3,241). No net benefit in extended life is given for this warranty project. Since the ratio is 1.50 (108,120 / 72,033), the cost of a warranty project is more than the cost of the control project and is not cost-effective.

CHAPTER 11: U.S. 36, EAST OF BYERS

11.1 Project Information

This warranty project was the first to have a five-year warranty period on HMA. The project is constructed in Arapahoe and Adam Counties on US 36 and extends 10.6 miles (21.2 lane-miles) beginning approximately18 miles east of Byers from Milepost 119.0 to Milepost 129.6. For reference, the Colorado project number is STA 0362-024 with a sub-account number of 13569.

The control project is adjacent to the warranty project in Arapahoe County on US 36 and extends easterly for 12.2 miles (24.4 lane-miles) beginning west of Byers from Milepost 100.8 to Milepost 113.0. For reference, the Colorado project number is STA 0362-026 with a sub-account number of 14275.

A comparison of the information from both the warranty and control projects is summarized in Table 10 below. The tonnage information in the following table represents the approximate quantity of HMA used to bid the projects.

Table 10 Comparison summary of the US 36 East of Byers / US 36 West of Byers project

	Five-Year Warranty Project	Control Project
Overlay Thickness	4 inches	2.5 inches
Rehabilitation Strategy	4-inch Cold Recycle	4-inch Cold Recycle
Award Date	August 9, 2002	March 3, 2003
Begin Construction Date	June 21, 2003	August 12, 2003
Project Acceptance Date	August 6, 2003	December 23, 2003
Facility Type	2-lane National Highway	2-lane National Highway
Tonnage	52,231	53,313
Engineer's Estimate, $/ton	$40.00	$36.00
Bid Price, $/ton	$46.00	$37.00
Economy of Scale, $/ton	$28.03	$27.93
Offset to the Unit Price, $/ton	$0.10	N/A
Mix Gradation	S	S
Type of Binder	PG 76-28	PG 64-28
Warranted HBP (5-yr), $/ton	$0.50	NA
Weigh-In-Motion Station	$45,000	NA
Quality Control Testing	($15,900)	NA
PET Reviews (1 required)	$5,400	NA
20-Year Design ESALs	1,846,000	1,500,000
Average Annual Daily Traffic	820	720
Single Unit Trucks (percent)	4.4	4.4
Combination Trucks (percent)	36.5	59.0

11.2 Initial Construction Cost

Using the information from the previous table, the standardized unit cost of the warranty project HMA is $45.90 per ton (46.00 – 0.10) which results in a cost of $2,397,403 (45.90 * 52,231). In addition, it cost $0.50 per ton for the warranty line item which results in a cost of $26,116 (0.50 * 52,231), the installation cost of the weigh-in-motion station is $45,000, and $5,400 for the PET review. This warranty project saved $15,900 in quality control testing. This resulted in a cost to CDOT of $115,945 per lane-mile (2,397,403 + 26,116 + 45,000 + 5,400 – 15,900)/21.2 to construct and monitor the warranty project. The cost to construct the control project is $80,843 per lane-mile (37.00 * 53,313)/24.4.

11.3 Maintenance and User Cost

The cost of CDOT roadway surface maintenance activities is summarized below in Figure 62 for the warranty and control project as collected in MMS. As of January 1, 2012 CDOT has spent a total of $1,648 per lane-mile on the warranty project while spending $1,008 per lane-mile on the control project.

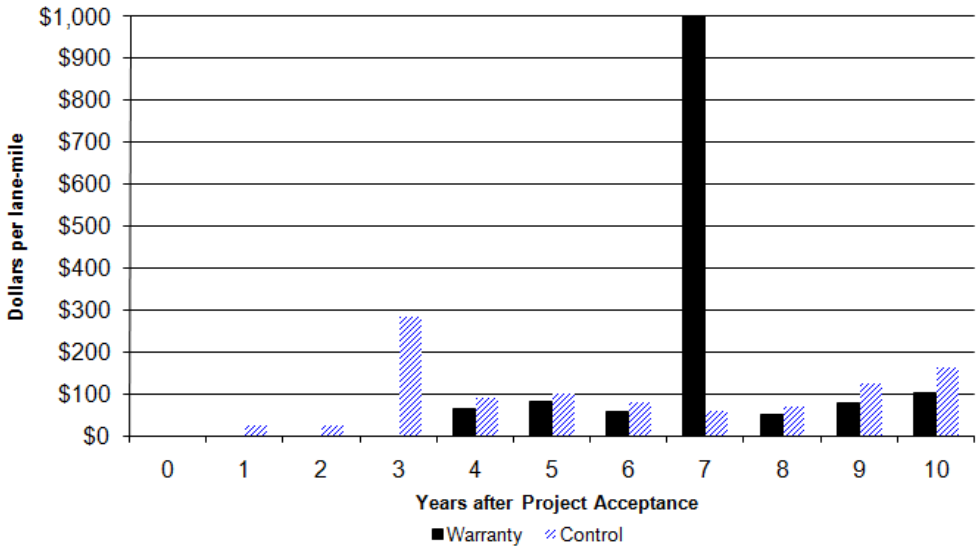

Figure 62. Comparison of the US 36 East of Byers / US 36 West of Byers maintenance cost

11.4 Performance Data

The IRI performance data shown in Figure 63 indicates that the warranty project is performing slightly worse than the control project. Based on this information, there is no expected benefit in extended life for the warranty project.

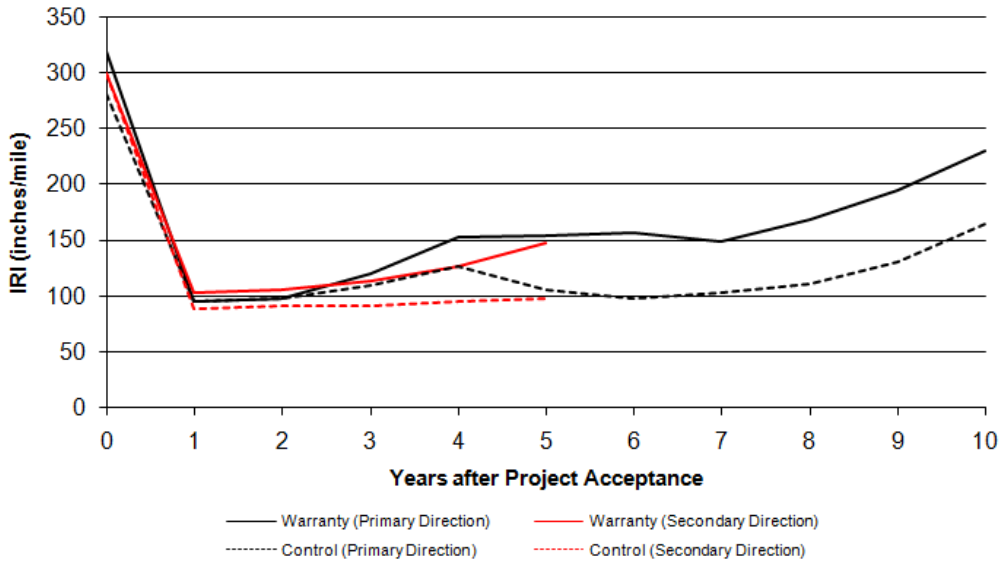

Figure 63. Comparison of the US 36 East of Byers / US 36 West of Byers IRI performance

The rut data shown in Figure 64 indicates that both projects are performing well and there is very little difference between the two projects. Based on this information, there is no expected benefit in extended life for the warranty project. The traffic data in Figure 65 shows that the loading on the warranty project was not exceeded during the 5-year warranty period.

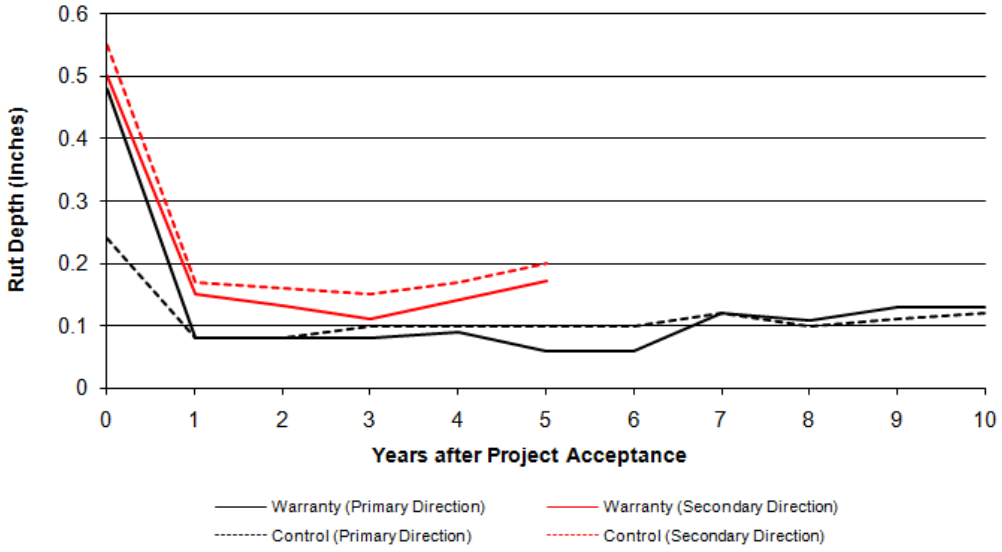

Figure 64. Comparison of the US 36 East of Byers/US 36 West of Byers rut depth performance

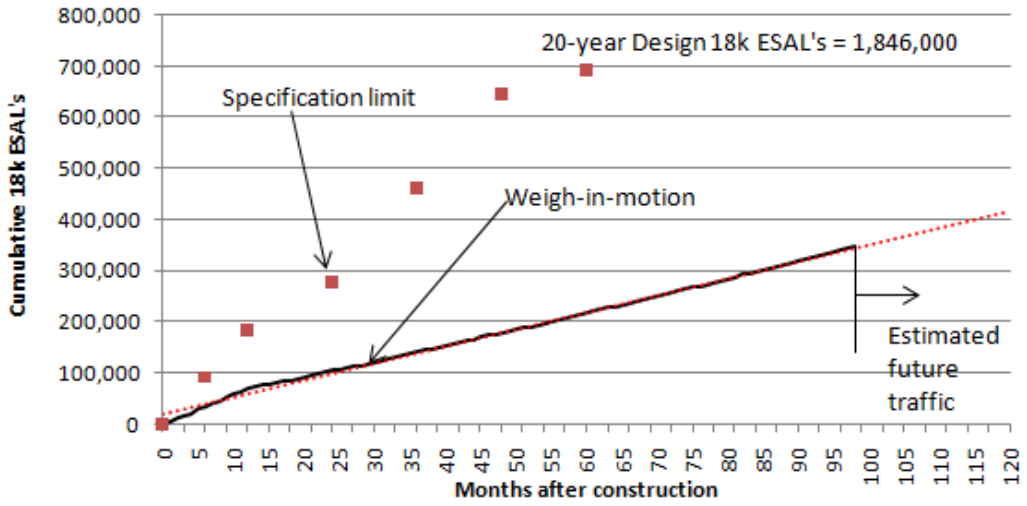

Figure 65. Cumulative weigh-in-motion 18k ESALs on US 36 warranty project

The fatigue data is included for information only. It is not a specified distress in the warranty project. Figure 66 indicates that each direction for both projects started with approximately the same amount of fatigue cracking. After 10 years of service life, the primary direction of the warranty project is performing poorly.

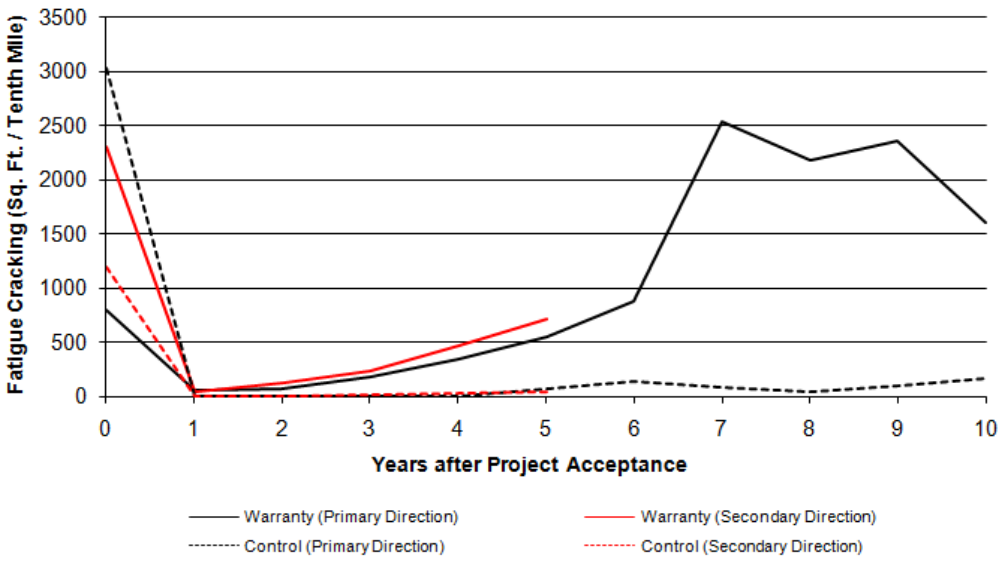

Figure 66. Comparison of the US 36 East of Byers/US 36 West of Byers fatigue cracking performance

The longitudinal cracking data in Figure 67 illustrates that each direction for both projects started with approximately the same amount of cracking. After 10 years of service life, the primary direction of the warranty project is performing poorly. The warranty project required remedial

action by the contractor. After 10 years of service, the control project is performing better. Based on this information, there is no expected benefit in extended life for the warranty project.

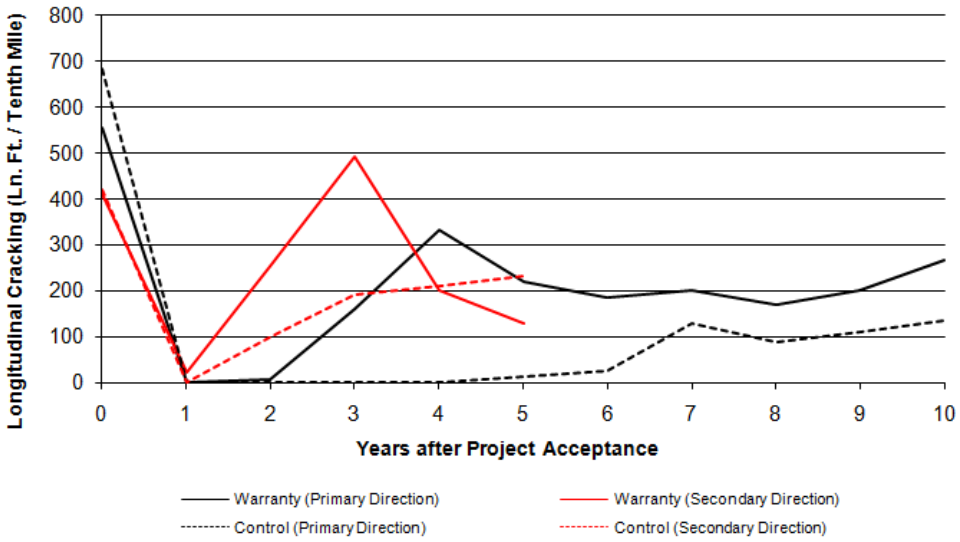

Figure 67. Comparison of the US 36 East of Byers/US 36 West of Byers longitudinal cracking performance

Figure 68 reveals that the warranty project is not performing well. After 10 years of service, the control project has fewer cracks. The PMS information indicates an increase in transverse cracking for the warranty project, but CDOT forces could not discover the same amount of cracking during the field review. Therefore, no remedial action was required by the contractor. From this information, no benefit in extended life can be determined for the warranty project.

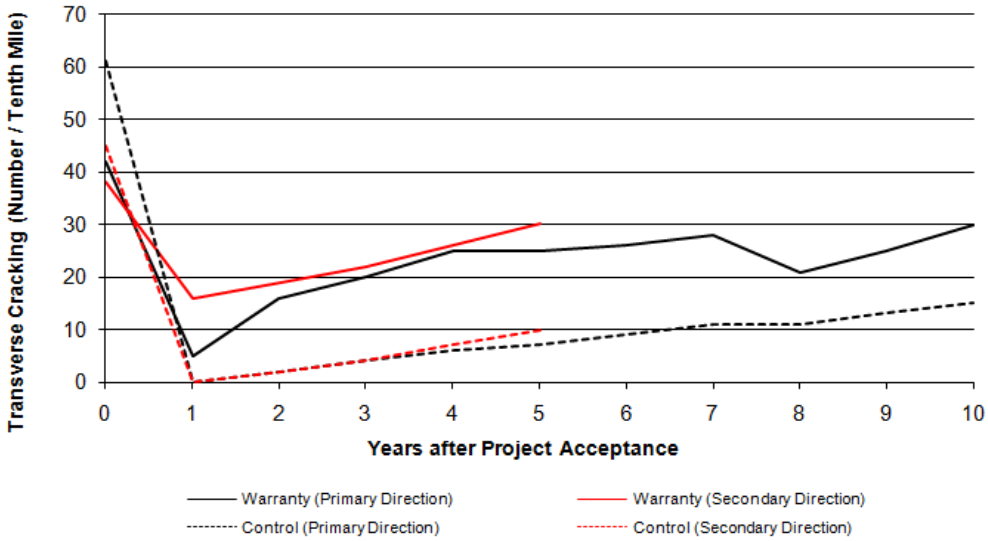

Figure 68. Comparison of US 36 East of Byers/US 36 West of Byers transverse cracking performance

11.4.1 PET Reviews

The PET evaluated this project at the end of the 5-year warranty period. The contractor was required to perform remedial action was required for longitudinal cracking.

11.5 Cost-Benefit Analysis

As of January 2012, the net cost on the warranty project is $117,593 per lane-mile (115,945 + 1,648) while the net cost on the control project is $81,851 per lane-mile (80,843 + 1,008). No net benefit in extended life is given for this warranty project. Since the ratio is 1.44 (117,593 / 81,851), the cost of a warranty project is more than the cost of the control project and is not cost-effective.

CHAPTER 12: U.S. 287, NORTH OF TED'S PLACE

12.1 Project Information

This is the second project constructed using a five-year warranty period on HMA. The warranty project is in Larimer County on US 287 and extends north of Ted's Place for 8.6 miles (17.2 lane-miles) from Milepost 356.2 to Milepost 364.8. For reference, the Colorado project number is NH 2873-126 with a sub-account number of 14301.

The control project is in Boulder County on S.H.119 and extends easterly for 1.6 miles (3.2 lane-miles) from Milepost 39.1 to Milepost 40.7. For reference, the Colorado project number is STA 1191-017 with a sub-account number of 13959.

A comparison of the information from both the warranty and control projects is summarized in Table 11 below. The tonnage information in the following table represents the approximate quantity of HMA used to bid the projects.

Table 11 Comparison summary of the US 287 / SH 119 project

	Five Year Warranty Project	Control Project
Overlay Thickness	2 inches	2 inches
Rehabilitation Strategy	¾-inch Leveling Course	2 to 4-inch Milling
Award Date	March 3, 2003	April 30, 2002
Begin Construction Date	April 15, 2003	July 5, 2002
Project Acceptance Date	May 1, 2003	December 17, 2002
Facility Type	2-lane National Highway	2-lane State Highway
Tonnage	34,448	7,952
Engineer's Estimate, $/ton	$45.00	$48.00
Bid Price, $/ton	$33.35	$40.70
Economy of Scale, $/ton	$26.39	$34.87
Offset to the Unit Price, $/ton	N/A	$8.48
Mix Gradation	S	S
Type of Binder	PG 58-34	PG 58-34
Warranty Line Item	$50,000	NA
Weigh-In-Motion Station	Not Required	NA
Quality Control Testing	($10,500)	NA
PET Reviews (1 required)	$5,400	NA
20-Year Design ESALs	7,549,664	1,463,276
Average Annual Daily Traffic	5,500	10,400
Single Unit Trucks (percent)	4.0	2.6
Combination Trucks (percent)	13.6	0.7

12.2 Initial Construction Cost

Using the information from the previous table, the cost of the warranty project HMA is $1,148,841 (33.35 * 34,448). In addition, it cost $50,000 for the warranty line item and $5,400 for the PET review. A weigh-in-motion station was not needed on this project because there was one in the general vicinity of the warranty project. This warranty project saved $10,500 in quality control testing. This resulted in a cost to CDOT of $69,403 per lane-mile (1,148,841 + 50,000 + 5,400 – 10,500)/17.2 to construct and monitor the warranty project. The cost to construct the control project is $80,067 per lane-mile ((40.70 – 8.48) * 7,952)/3.2.

12.3 Maintenance and User Cost

The cost of CDOT roadway surface maintenance activities is summarized below in Figure 69 for the warranty and control project as collected in MMS. As of January 1, 2012 CDOT forces has spent a total of $4,026 per lane-mile on the warranty project while spending $14,163 per lane mile on the control project.

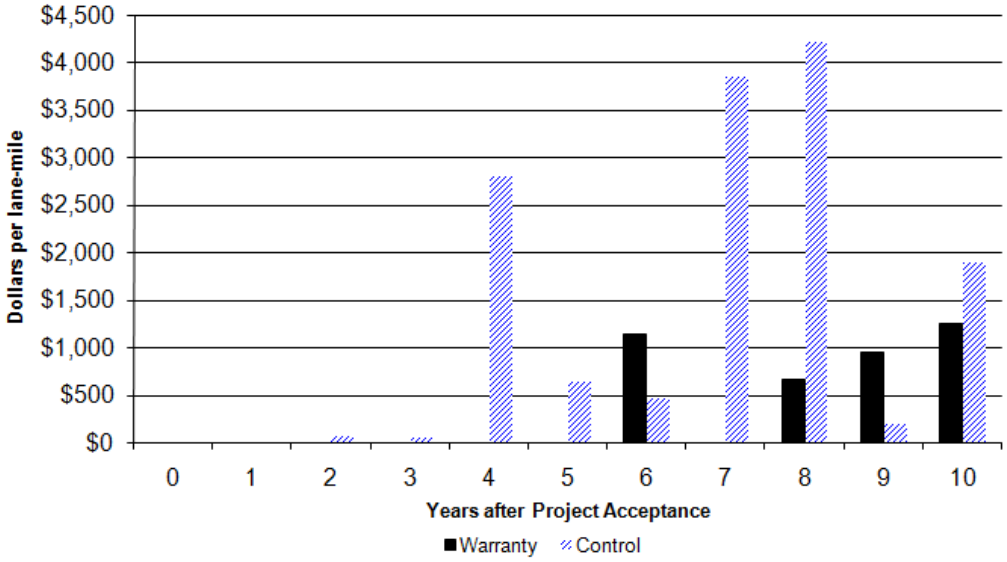

Figure 69. Comparison of the US 287 / SH 119 maintenance cost

12.4 Performance Data

In the five years after acceptance, the IRI performance data shown in Figure 70 indicates that the warranty project is performing better than the control project. While both projects started with the same IRI, the control project was not constructed as well as the warranty project. Based on this information, the benefit in extended life for the warranty project will probably be greater than five years. We will use a benefit of $101,000 per lane mile (5 * 20,200) for the extended life.

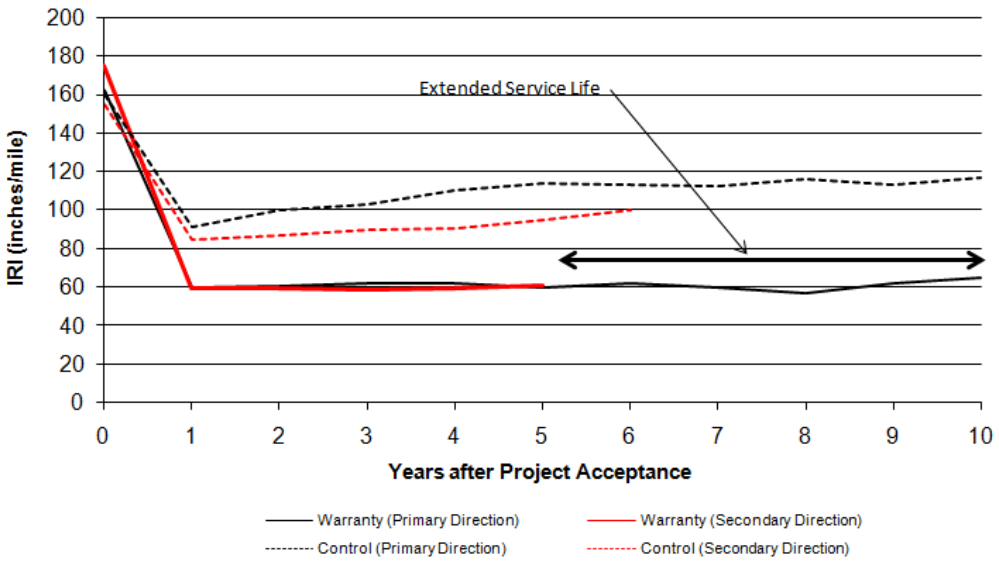

Figure 70. Comparison of the US 287 / SH 119 IRI performance

The rut data shown in Figure 71 indicates that the warranty project is performing better than the control project. While both projects started with the same IRI, the control project was not constructed as well as the warranty project. Based on this information, the benefit in extended life for the warranty project will probably be greater than five years. We will use a benefit of $101,000 per lane mile (5 * 20,200) for the extended life. The traffic data indicated in Figure 72 shows that the loading on the warranty project was not exceeded during the 5-year warranty period.

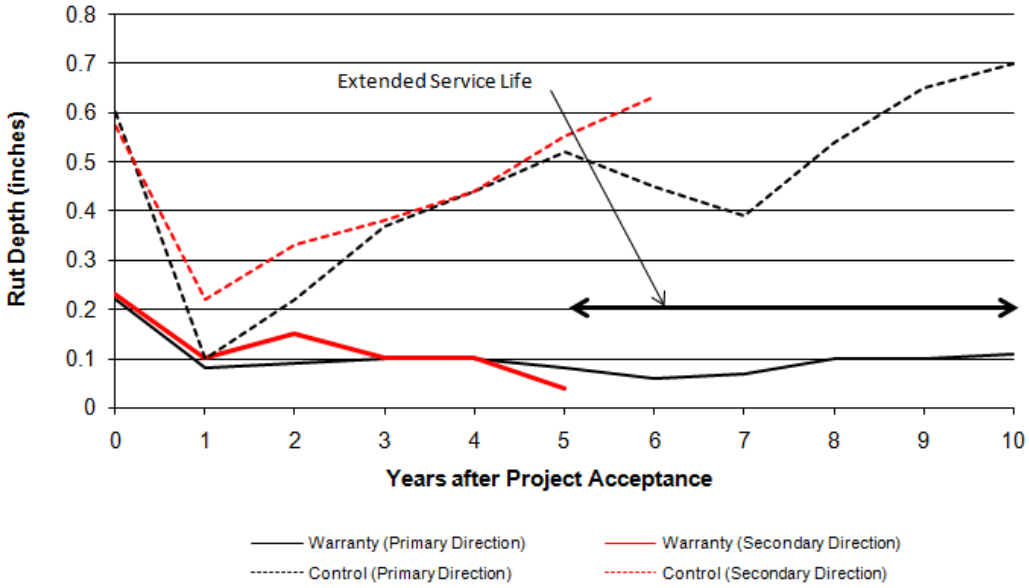

Figure 71. Comparison of the US 287 / SH 119 rut depth performance

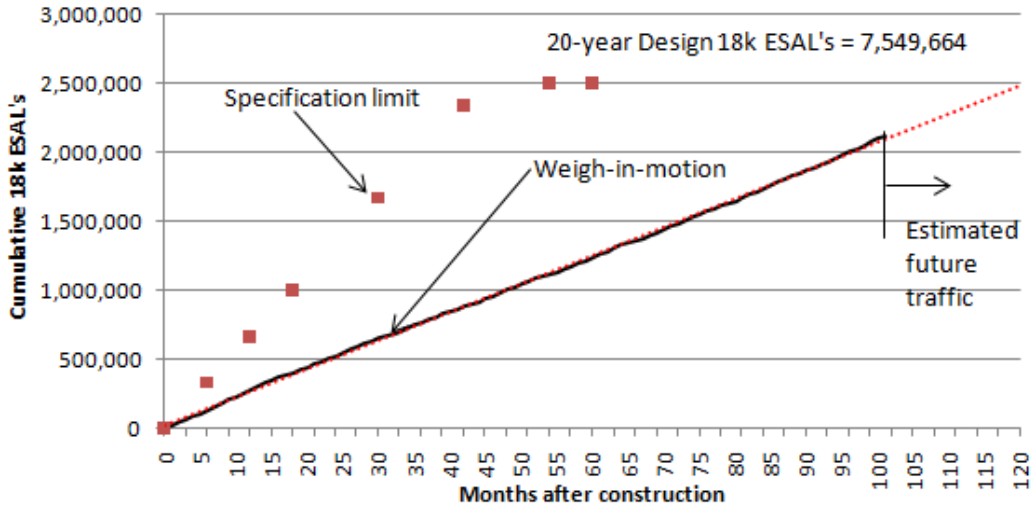

Figure 72. Cumulative weigh-in-motion 18k ESALs on the US 287 warranty project

The fatigue data is included for information only. It is not a specified distress in the warranty project. Figure 73 indicates that the control project started with twice as much cracking. However, after 10 years of service life, the primary direction of the warranty project is not doing as well as the primary direction of the control project.

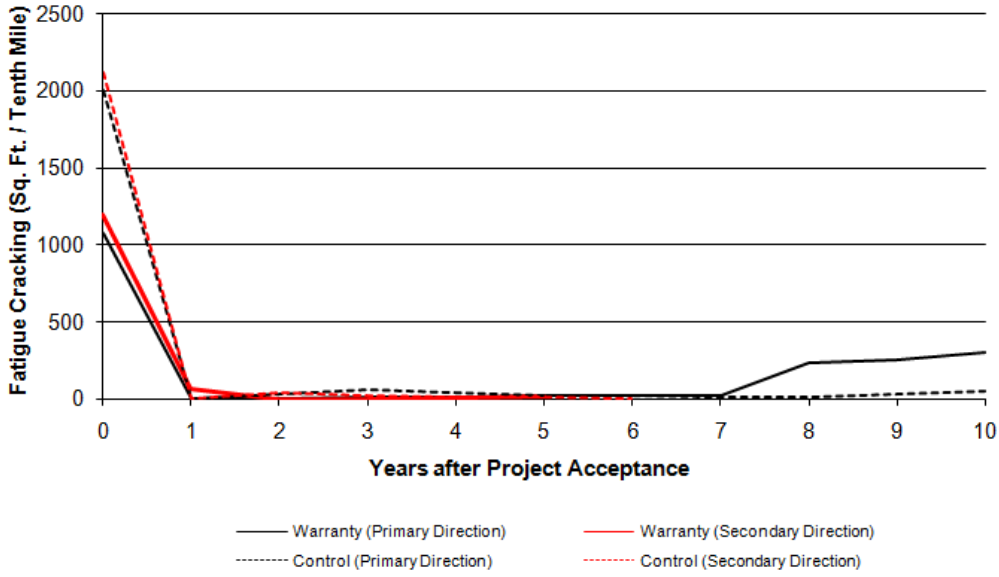

Figure 73. Comparison of the US 287 / SH 119 fatigue cracking performance

The longitudinal cracking data in Figure 74 illustrates that the control project started with worse cracking. After 10 years of service life, the primary direction of the warranty project is performing poorly. The warranty project did not required remedial action by the contractor because the distress level was low. After 10 years of service, the control project is performing better. Based on this information, there is no expected benefit in extended life for the warranty project.

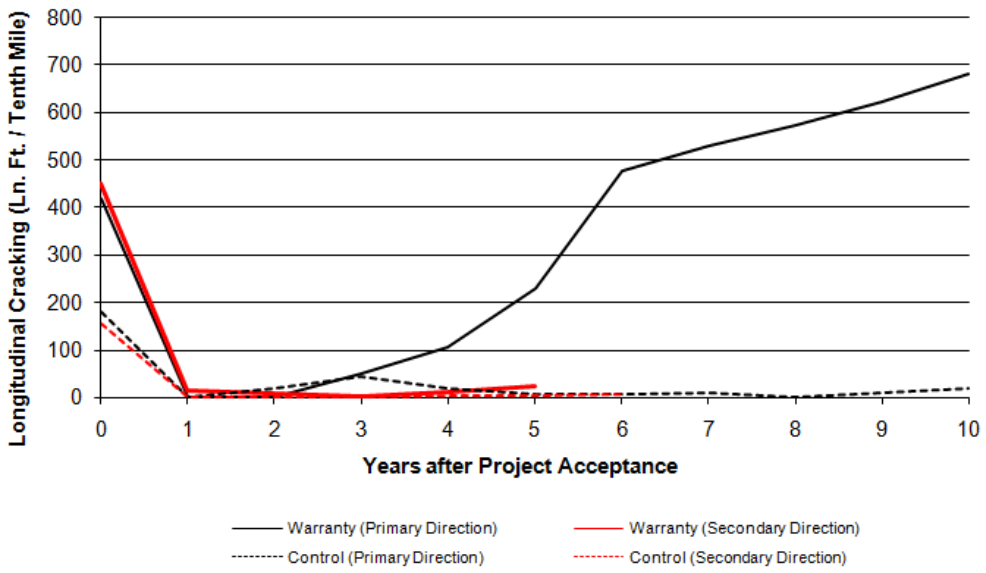

Figure 74. Comparison of the US 287 / SH 119 longitudinal cracking performance

Figure 75 reveals that the control project is performing slightly better than the warranty project. After 10 years of service, the control project has fewer cracks. The PMS information indicates an increase in transverse cracking for the warranty project, but they did not meet the level required by the specification for remedial action. From this information, no benefit in extended life can be determined for the warranty project.

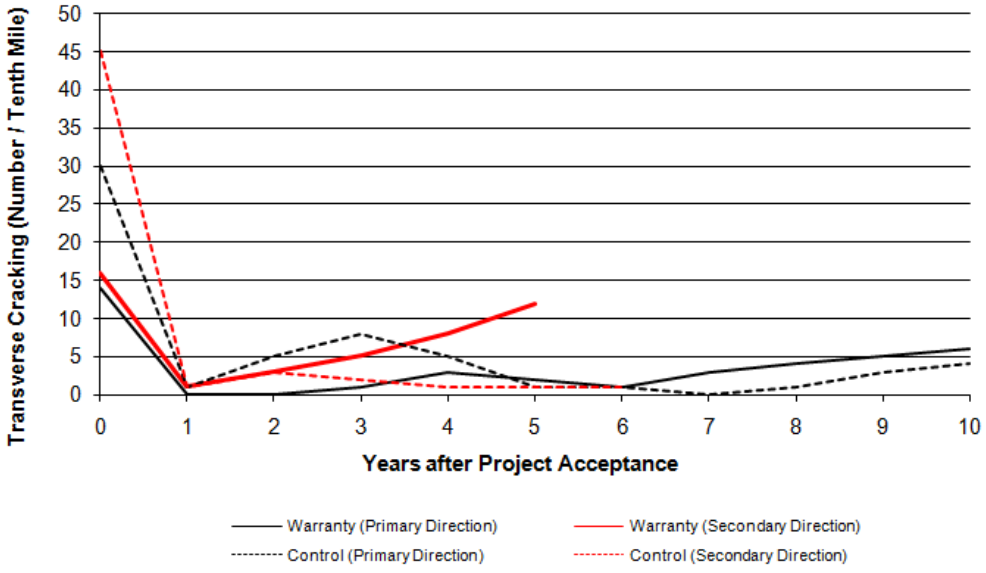

Figure 75. Comparison of the US 287 / SH 119 transverse cracking performance

12.4.1 PET Reviews

At the end of the five-year warranty period, one evaluation was done by the PET. The majority of the transverse cracking that was observed was found to be present on the outside shoulder throughout the super-elevated sections of the study area. The cracking observed do not meet the level required for remedial action by the contractor.

12.5 Cost-Benefit Analysis

As of January 2012, the net cost on the warranty project is $73,429 per lane-mile (69,403 + 4,026) while the net cost on the control project is $94,230 per lane-mile (80,067 + 14,163). Since two of the four performance measures indicated that there wasn't any extended life, no net benefit is given for this warranty project. Since the ratio is 0.78 (73,429 / 94,230), the cost of a warranty project is less than the cost of the control project and is cost-effective.

CHAPTER 13: SUMMARY OF FINDINGS AND CONCLUSIONS

13.1 Construction Information

In this report, 10 pairs of warranty and control projects were compared to assess their relative costs and benefits as of January 1, 2012. These three and five-year warranty projects were constructed between 1998 and 2003. Their current performance life is about ten years. Each set was carefully selected so that the projects had similar characteristics in terms of pre-overlay repair work, functional class, design life, and other features, in order to minimize bias. Overall, 214.6 lane-miles of warranty projects were constructed. Their cost and performance was compared to 276.6 lane-miles of control projects.

The average initial construction cost of the warranty projects was $79,176 per lane-mile while the average cost for the control projects was $71,964 per lane mile. The average cost to CDOT for the warranty was $2,624 per lane mile and the weigh-in-motion station cost about $2,924 per lane-mile. The average cost to CDOT for the Pavement Evaluation Team was $583 per lane-mile while CDOT had a savings due to reduced verification testing by CDOT of about $708 per lane-mile. Therefore, warranty projects cost $12,635 per lane mile more for the initial construction. This amount could be reduced by about $3,507 if CDOT were to eliminate the PET and the WIM station.

An analysis of each warranty project for unbalanced bids was conducted. The line item profiles for each of the warranty projects were obtained from the CDOT Cost Estimating Unit. This profile was used to identify those bid items most responsible for bidding deviations. In general, there was no significant degree of unbalancing in all warranty projects.

After completion of the projects, the contractors were asked what they would do differently. The contractors that were the successful low bidders indicated that they would do very little, if anything differently. It is likely that the bidding results on these warranty projects were similar to many of CDOT's standard projects.

13.2 Contractor Innovation on Projects

For the ten constructed warranty projects, three of them had experimental features added by the contractor. On I-25 at Fountain, the contractor did research to evaluate a variety of methods to minimize reflective cracking. For more information on this experimental feature, please see CDOT Research Report Number CDOT-DTD-R-2003-5 entitled *Crack Reduction Strategies on a Pavement Warranty Project (Interstate 25 at Fountain, Colorado).* On the I-25 North of Pueblo project, there was an experiment done with the longitudinal joint construction and use of recycled asphalt pavement (RAP.) On I-70 at Eagle, there was an evaluation of joint tape to improve performance of longitudinal joints. The contractors on the control projects had no experimental features.

13.3 Performance Information

A statistical analysis of the PMS tenth-mile segment data showed that the warranty pavements were constructed slightly rougher and with less consistency as the control pavements. A comparison of the IRI is shown in Figure 76. An analysis of the tenth-mile segments from the PMS data after one year of service life indicates that the warranty pavements had an average IRI of about 62 inches per mile with a standard deviation of 20. The control pavements had an average IRI of 60 inches per mile with a standard deviation of 21 inches. About 52 percent of the warranty segments have an IRI of less than 60 inches per mile, whereas about 62 percent of the control segments meet the same criteria.

After gathering three years of performance information, the data showed that the warranty pavements were slightly smoother with a more consistent ride as compared to the control projects. The warranty pavements had an average IRI of 68.8 inches per mile with a standard deviation of 16.3 while the control pavements had an average IRI of 75.1 inches per mile with a standard deviation of 20.9 inches per mile. About 44 percent of the warranty segments have an IRI of less than 60 inches per mile, whereas about 51 percent of the control segments meet the same criteria.

After ten years of service life, the warranty pavements were slightly rougher. The warranty pavements had an average IRI of 79.7 inches per mile with a standard deviation of 23.6 while the control pavements had an average IRI of 70.2 inches per mile with a standard deviation of 21.1 inches per mile. About 22 percent of the warranty segments have an IRI of less than 60 inches per mile, whereas about 34 percent of the control segments meet the same criteria.

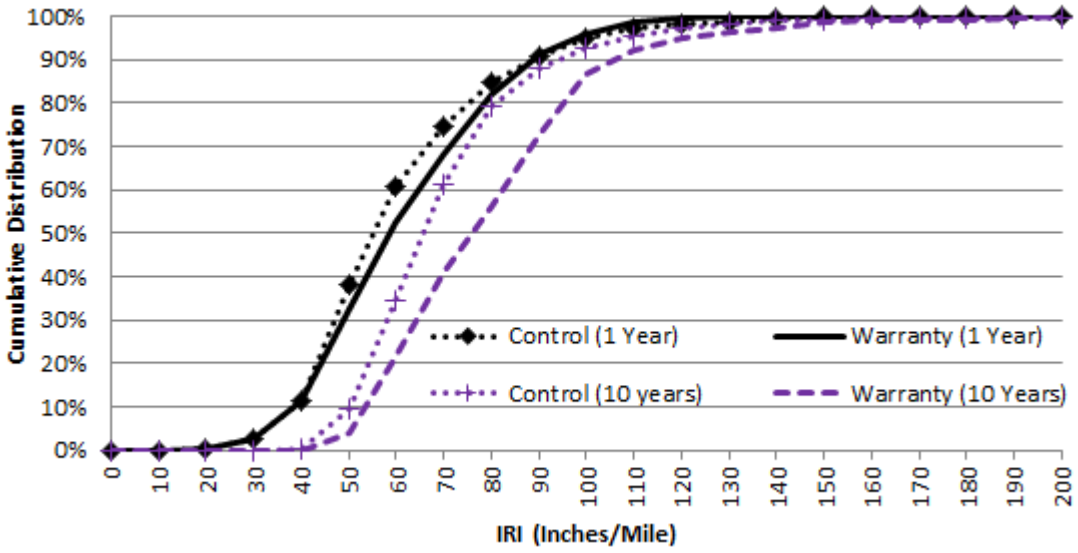

Figure 76. IRI comparison

An analysis of the tenth-mile segments from the PMS data indicates that the warranty projects were constructed with about half the rut depth and with about the same consistency. The warranty pavements had an average rut depth of 0.08 inches with a standard deviation of 0.05 inches while the control pavements had an average of 0.14 inches and a standard deviation of 0.06 inches. A

comparison of the rut depth is shown in Figure 77. One year after construction indicates that about 80 percent the warranty segments have less than 0.1 inch rut depth, whereas about 40 percent of the control segments meet the same criteria.

After collecting three years of information from the projects, the data showed that the warranty pavements had slightly deeper ruts with less variability as compared to the control projects. The warranty segments had an average rut depth of 0.20 inches with a standard deviation of 0.08 inches while the control segments had an average of 0.14 inches with a standard deviation of 0.12 inches. A comparison of the rut depth indicates that 68 percent the warranty projects have less than 0.1 inch rut depth, whereas about 69 percent of the control projects meet the same criteria.

After ten years of service life, the warranty pavements had deeper ruts. The warranty segments had an average rut depth of 0.22 inches with a standard deviation of 0.11 inches while the control segments had an average of 0.17 inches with a standard deviation of 0.13 inches. Only 15 percent of the warranty segments have a rut depth of less than 0.1 inch, whereas about 35 percent of the control segments meet the same criteria.

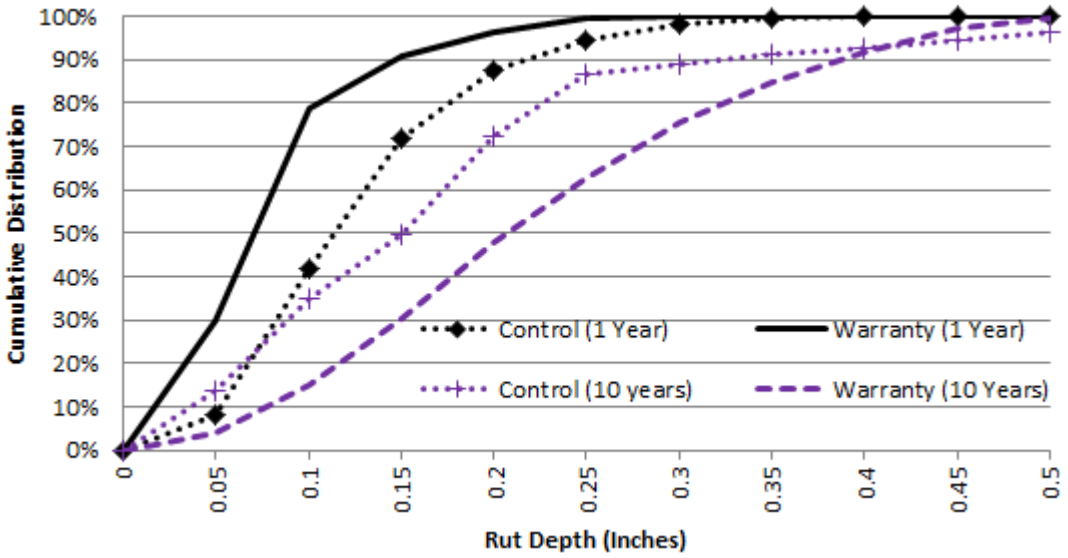

Figure 77. Rut depth comparison

An analysis of the tenth-mile segments from the PMS data indicates that both projects were constructed with the same amount (197 linear feet) of longitudinal cracks and with about the same consistency. A comparison of the longitudinal cracking is shown in Figure 78. One year after construction indicates that about 98 percent the warranty segments have less than 100 linear feet of cracking per tenth mile segment, whereas about 90 percent of the control segments meet the same criteria.

After collecting three years of information from the projects, the data showed that the warranty pavements had about twice the amount of cracking. The warranty segments had an average of about 101 linear feet with a standard deviation of about 167 linear feet while the control segments had an average of 54 linear feet with a standard deviation of about 109 linear feet. A comparison

of the cracking indicates that 73 percent the warranty projects have less than 100 linear feet, whereas about 82 percent of the control projects meet the same criteria.

After ten years of service life, the warranty pavements had slightly less longitudinal cracking. The warranty segments had an average of 314 linear feet with a standard deviation of 209 linear feet while the control segments had an average of 337 linear feet with a standard deviation of 372 linear feet per tenth mile segment. Only 21 percent of the warranty segments have less than 100 linear feet of longitudinal cracking, whereas about 34 percent of the control segments meet the same criteria. However, the control projects had 12.4 miles with over 1,000 linear feet of cracking. None of the segments on the warranty projects exceeded 1,000 linear feet of cracking.

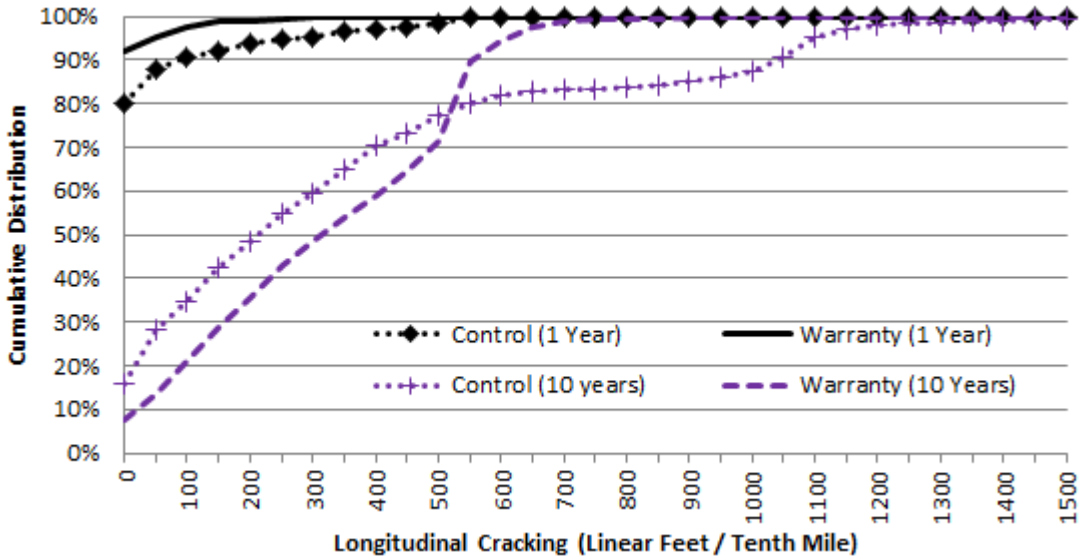

Figure 78. Longitudinal cracking comparison

An analysis of the tenth-mile segments from the PMS data indicates that the warranty projects were constructed with about four more transverse cracks than the control projects with about the same consistency. A comparison of the transverse cracking is shown in Figure 79. One year after construction indicates that about 99 percent the warranty segments have less than 10 transverse cracks per tenth mile segment, whereas about 82 percent of the control segments meet the same criteria.

After collecting three years of information from the projects, the data showed that the control pavements had about three times the amount of cracking. The warranty segments had an average of 1.6 cracks with a standard deviation of 3.6 cracks while the control segments had an average of 4.2 cracks with a standard deviation of 7.1 cracks. A comparison of the transverse cracking indicates that 97 percent the warranty projects have less than 10 cracks, whereas about 82 percent of the control projects meet the same criteria.

After ten years of service life, the warranty pavements had slightly more transverse cracking. The warranty segments had an average of 13.8 with a standard deviation of 13.5 cracks while the control segments had an average of 9.9 with a standard deviation of 10.4 cracks per tenth mile

segment. Only 45 percent of the warranty segments have less than 10 transverse cracks, whereas about 60 percent of the control segments meet the same criteria.

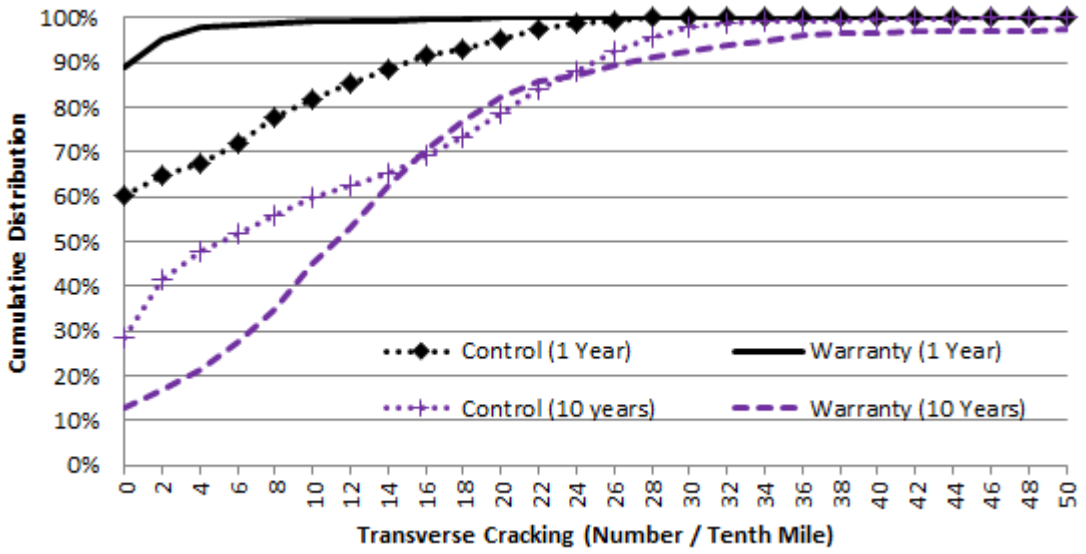

Figure 79. Transverse cracking comparison

Looking at the projects' average IRI performance information as shown in Figure 80, both pavements' trend lines start at about 80 inches per mile and increase at the same rate.

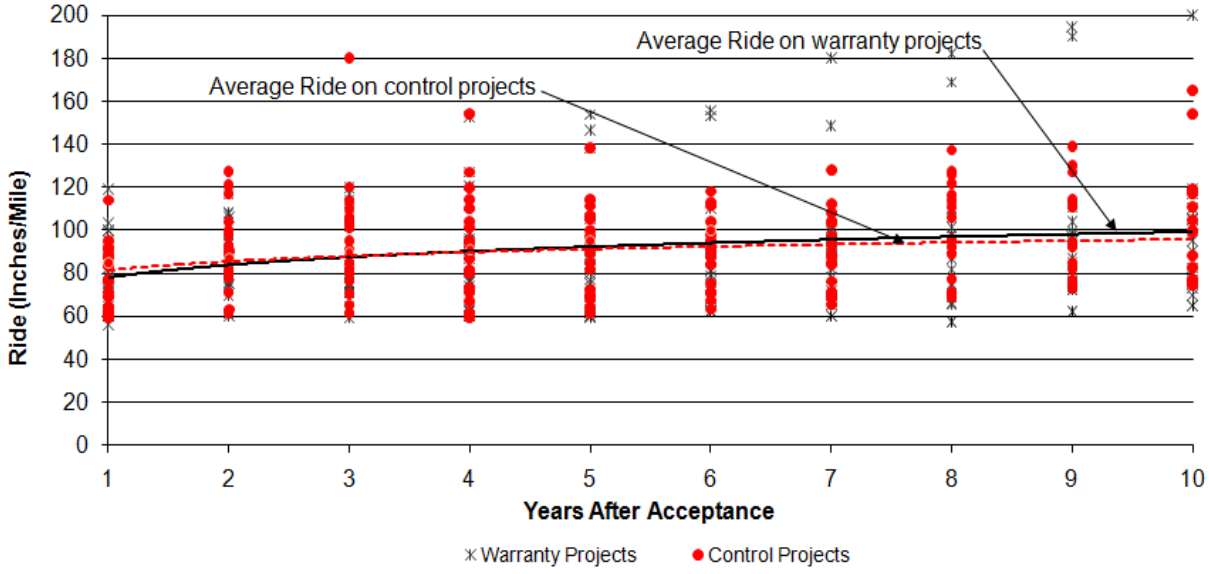

Figure 80. Average IRI performance

Regarding the projects' trend lines for average rut depth performance information as shown in Figure 81, the control projects increased at a faster rate. After ten years of service life, the control projects had about a 0.05 inch deeper rut.

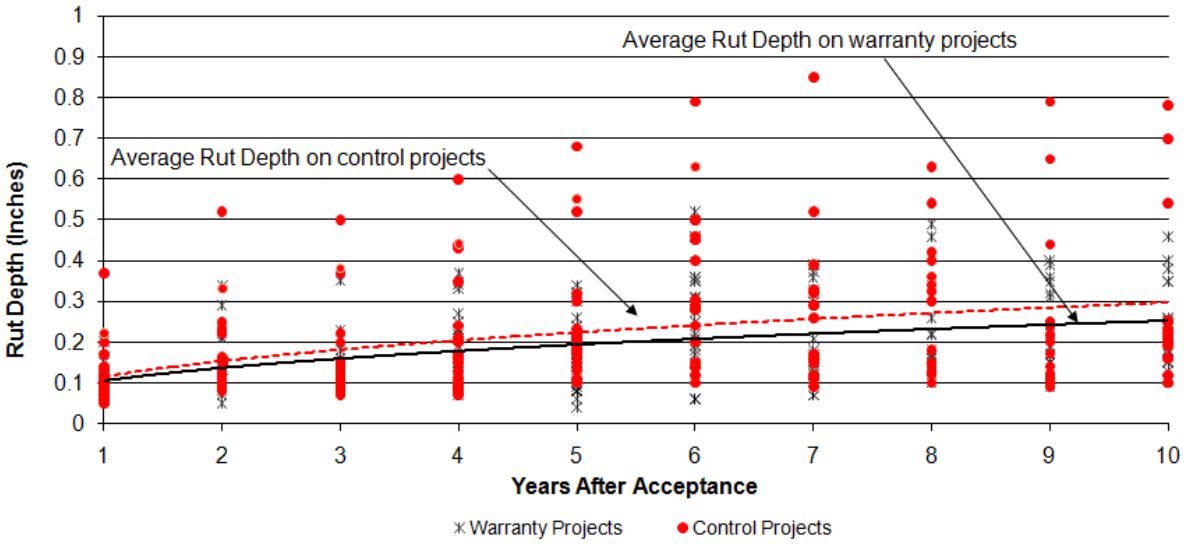

Figure 81. Average rut depth performance

Reviewing the projects' trend lines for the performance of longitudinal cracking information as shown in Figure 82, both projects performed about the same. After ten years of service life, little difference can be seen between the projects.

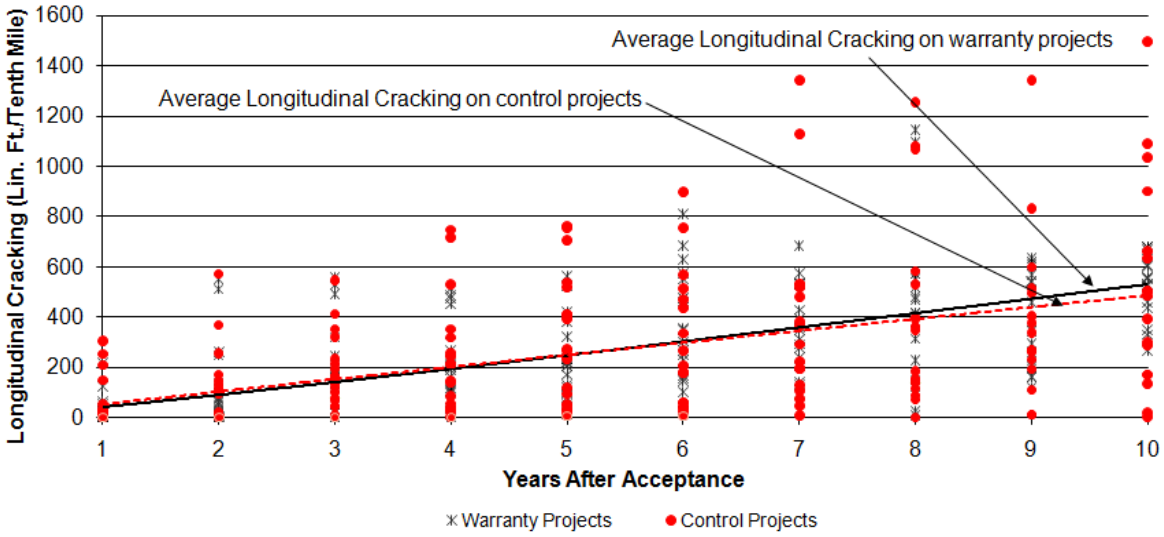

Figure 82. Average longitudinal cracking performance

Studying the projects' trend lines for average transverse cracking performance information as shown in Figure 83, the warranty projects increased at a much faster rate. After ten years of service life, the control projects had about 15 transverse cracks while the control projects had about 24 cracks.

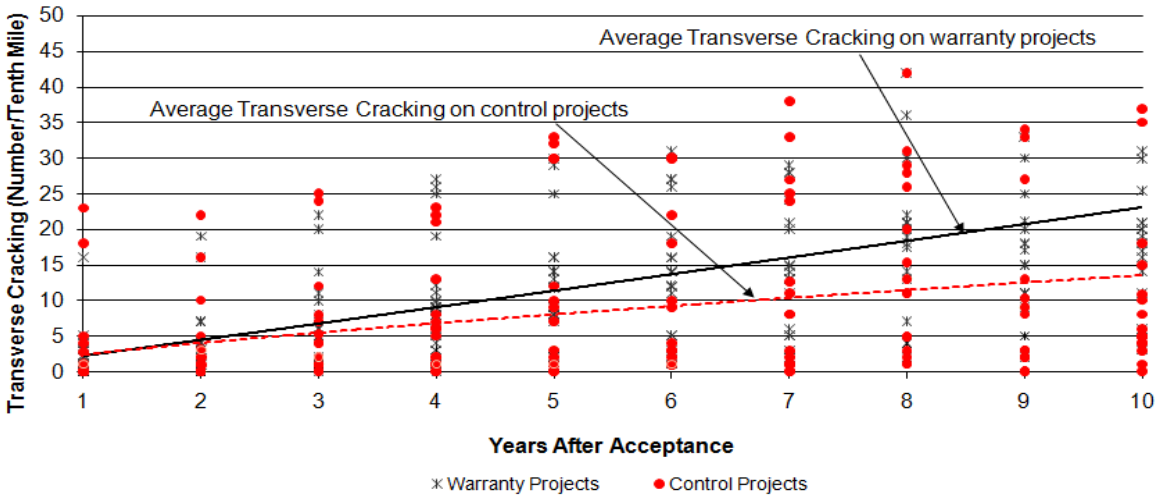

Figure 83. Average transverse cracking performance

13.4 Maintenance and User Cost

During the period of the warranty, no maintenance costs were borne by CDOT forces. The PET required corrective work on three of the warranty projects at no cost to CDOT. As of January 1, 2012, the average total cost of maintenance for the warranty projects was $14,282 per lane-mile, while the average for the control projects was $19,898 per lane-mile. Therefore, the warranty project cost about $5,616 per lane-mile less to maintain over the 10 year period. Looking at the projects' average maintenance cost as shown in Figure 84, the maintenance cost on warranty pavements are increasing at a greater rate than the control pavements after 10 years of service life.

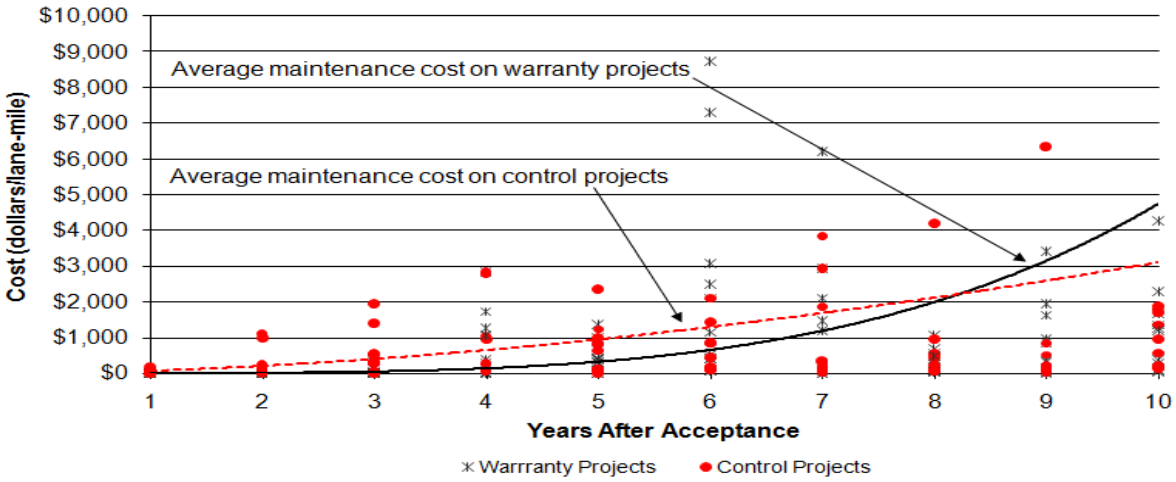

Figure 84. Average maintenance cost

13.5 Project Summary

Each project was individually evaluated to determine if there was an overall cost savings that resulted from the warranty. The summary of the cost data is shown in Table 12. Based on the current data from this report, only three of the ten warranty projects had a cost savings during the

construction of the project. Four of the warranty projects were cost-effective to construct and maintain over the 10-year analysis period.

Table 12 Summary of Cost Data (Dollars per Lane-Mile)

Location	Initial HMA Construction Cost	Warranty Line Item	WIM Station	PET	QC Testing	Total Maintenance Cost	Total Cost
I-25, Fountain – South	101,470	N/A	N/A	1,066	(888)	8,178	109,826
Control Project	66,778	N/A	N/A	N/A	N/A	8,692	75,470
C 470, Santa Fe to Wadsworth Blvd.	56,645	N/A	4,583	1,350	(500)	86,508	148,586
Control Project	47,736	N/A	N/A	N/A	N/A	118,851	166,587
US 36, E & W of Superior	44,701	N/A	4,288	900	(433)	9,854	59,310
Control Project	42,653	N/A	N/A	N/A	N/A	4,317	46,970
I-25, North of Pueblo	119,389	2,358	2,759	764	(1,019)	9,164	133,415
Control Project	63,939	N/A	N/A	N/A	N/A	8,692	72,631
I-70, Eagle - East	70,237	2,917	1,201	340	(649)	4,369	78,415
Control Project	55,184	N/A	N/A	N/A	N/A	13,215	68,399
US 50, East of Kannah Crk.	59,113	3,425	1,884	185	(627)	4,535	68,515
Control Project	135,129	N/A	N/A	N/A	N/A	4,924	140,053
SH 63, South of I-76	60,337	2,407	3,630	333	(537)	9,397	75,567
Control Project	79,140	N/A	N/A	N/A	N/A	21,872	101,012
I-25, Ray Nixon – South	100,605	3,125	N/A	321	(1,071)	5,140	108,120
Control Project	68,792	N/A	N/A	N/A	N/A	3,241	72,033
US 36, East of Byers	113,085	1,232	2,123	255	(750)	1,648	117,593
Control Project	80,843	N/A	N/A	N/A	N/A	1,008	81,851
US 287, North of Ted's Place	66,793	2,907	N/A	314	(610)	4,026	73,430
Control Project	80,067	N/A	N/A	N/A	N/A	14,163	94,230
Warranty Average	**79,238**	**2,624**	**2,924**	**583**	**(708)**	**14,282**	
Control Average	**72,026**	**N/A**	**N/A**	**N/A**	**N/A**	**19,898**	

Another evaluation was to determine if there was improved performance that resulted from the warranty. None of the ten warranty projects had improved performance.

On average, the warranty projects were not worthwhile with a cost-benefit ratio of 1.16. The summary of this information is shown in Table 13.

Table 13 Project Summary

Warranty Project	Years of Performance Data	Construction Cost Savings	Overall Improved Performance	Cost-Benefit Ratio
I-25 at Fountain	10	No	No	1.46
C-470 at Santa Fe	10	No	No*	0.89
US-36 at Superior	10	No	No	1.25
I-25 North of Pueblo	10	No	No	1.84
I-70 at Eagle	10	Yes	No	1.15
US-50 at Kannah Creek	10	Yes	No	0.49
SH-63 at I-76	10	No	No	0.75
I-25 at Ray Nixon	10	Yes	No	1.50
US-36 at Byers	9	No	No	1.44
US-287 at Ted's Place	9	Yes	No	0.78
			Average =	1.16

* In the sixth year after the warranty project was constructed, it needed minor rehabilitation. The control project needed rehabilitation after eight years.

The cost –benefit ratio could be reduced to 1.05 if the weigh-in-motion stations and the pavement evaluation teams were removed from the specifications.

13.6 Conclusions

After 10 years of comparison performance information between the warranty and control projects, the three and five-year, short-term warranty pavements had a rougher ride, slightly deeper ruts, a few more transverse cracks, and slightly less longitudinal cracking. The warranty projects cost more to construct but less to maintain. The average cost/benefit ratio was 1.16. There is a shift in risk and responsibility as a result of the warranty projects, but at this time, there was no tangible benefit identified. Based on the evaluation of these pavements, the implementation of short-term warranties of HMA is currently not a cost-effective tool for CDOT to implement.

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APPENDIX A: SENATE BILL 97-128

1997

An Act

SENATE BILL 97-128

BY SENATORS Duke, Ament, Arnold, Coffman, Congrove, Dennis, Linkhart, Mutzebaugh, Powers, Tebedo, Rupert, and Weddig;
also REPRESENTATIVES Swenson, Owen, Allen, June, Lamborn, Lawrence, May, McElhany, Salaz, Agler, Arrington, Dean, Gotlieb, Morrison, Nichol, Pfiffner, Schwarz, and Tucker.

CONCERNING A PILOT PROGRAM TO ALLOW THE DEPARTMENT OF TRANSPORTATION TO ENTER INTO CONTRACTS THAT REQUIRE A WARRANTY FOR QUALIFIED HOT BITUMINOUS PAVEMENT PROJECTS.

Be it enacted by the General Assembly of the State of Colorado:

SECTION 1. 43-1-106, Colorado Revised Statutes, 1993 Repl. Vol., as amended, is amended BY THE ADDITION OF A NEW SUBSECTION to read:

43-1-106. Transportation commission - powers and duties. (16) (a) THE COMMISSION SHALL ESTABLISH A PILOT PROGRAM FOR THE WARRANTY OF QUALIFIED HOT BITUMINOUS PAVEMENT PROJECTS. THE PILOT PROGRAM SHALL BEGIN NO LATER THAN JULY 1, 1997, AND SHALL END JULY 1, 2002, UNLESS EXTENDED BY THE GENERAL ASSEMBLY ACTING BY BILL. THE COMMISSION IS HEREBY AUTHORIZED TO PREPARE CONTRACT SPECIFICATIONS AND ENTER INTO CONTRACTS FOR QUALIFIED BITUMINOUS PAVEMENT PROJECTS IN THE STATE AND REQUIRE CONTRACTORS TO WARRANT WORK ON SUCH PROJECTS FOR A PERIOD NOT TO EXCEED THREE YEARS FOLLOWING THE COMPLETION OF A QUALIFIED HOT BITUMINOUS PAVEMENT PROJECT. NO CONTRACTOR SHALL BE HELD RESPONSIBLE UNDER

Capital letters indicate new material added to existing statutes; dashes through words indicate deletions from existing statutes and such material not part of act.

A WARRANTY IMPOSED PURSUANT TO THIS SUBSECTION (16) FOR PAVEMENT DISTRESSES THAT ARE CAUSED BY FACTORS BEYOND THE CONTROL OF THE CONTRACTOR. NO CONTRACTOR SHALL BE HELD RESPONSIBLE UNDER A WARRANTY IMPOSED PURSUANT TO THIS SUBSECTION (16) UNLESS THE DEPARTMENT COMPLIES WITH THE CONDITIONS STATED THEREIN. FOR PURPOSES OF THIS SUBSECTION (16):

(I) "QUALIFIED HOT BITUMINOUS PAVEMENT PROJECT" MEANS A PROJECT UNDERTAKEN AS PART OF A PILOT PROGRAM COMPRISED OF THREE PROJECTS BID DURING 1997 OR 1998 AND APPROVED BY THE COMMISSION AND A TECHNICAL ADVISORY COMMITTEE SELECTED PURSUANT TO PARAGRAPH (d) OF THIS SUBSECTION (16). SUCH PROJECTS MUST BE CONSTRUCTED ALONG THE FRONT RANGE.

(II) "WARRANTY" MEANS A WRITTEN WARRANTY, SO LABELED, OF THE HOT BITUMINOUS PAVEMENT WORK TO BE PERFORMED IN CONNECTION WITH A QUALIFIED HOT BITUMINOUS PAVEMENT PROJECT, INCLUDING ANY TERMS OR CONDITIONS PRECEDENT TO THE ENFORCEMENT OF OBLIGATIONS UNDER SUCH WARRANTY.

(b) ANY WARRANTY OBTAINED BY THE COMMISSION PURSUANT TO PARAGRAPH (a) OF THIS SUBSECTION (16) SHALL REMAIN VALID FOR THE DURATION OF THE WARRANTY'S TERM UNLESS THE COMMISSION AND CONTRACTOR AGREE OTHERWISE.

(c) WHEN A PROVISION HAS BEEN MADE FOR THE NECESSARY FUNDS, INCLUDING ANY FEDERAL FUNDS, FOR ANY QUALIFIED HOT BITUMINOUS PAVEMENT PROJECT AND WHEN THE PROJECT HAS BEEN APPROVED BY THE PROPER FEDERAL AUTHORITIES, THE COMMISSION MAY PROCEED TO REQUIRE A WARRANTY FOR A QUALIFIED HOT BITUMINOUS PAVEMENT PROJECT AS PROVIDED IN THIS SUBSECTION (16) WITH DUE REGARD TO ANY APPLICABLE FEDERAL REQUIREMENT OR REGULATION.

(d) A TECHNICAL ADVISORY COMMITTEE SHALL SELECT THOSE PAVING PROJECTS THAT WILL BE CONSTRUCTED AS PART OF THE PILOT PROGRAM CREATED PURSUANT TO THIS SUBSECTION (16) AND THE BITUMINOUS PAVEMENT WARRANTY PROGRAM DEVELOPED BY THE DEPARTMENT OF TRANSPORTATION. SUCH COMMITTEE SHALL BE SELECTED BY THE COMMISSION AND CONSIST OF PRIVATE BITUMINOUS PAVEMENT CONTRACTORS AND DEPARTMENT OFFICIALS WHO ARE KNOWLEDGEABLE ABOUT BITUMINOUS PAVING AND THE UNITED STATES DEPARTMENT OF TRANSPORTATION STRATEGIC HIGHWAY RESEARCH PROGRAM, AS IT APPLIES TO THE PROVISIONS OF THIS SUBSECTION (16).

(e) ALL PAVING PROJECTS CONSTRUCTED PURSUANT TO THIS SUBSECTION (16) SHALL BE SUBJECT TO A COST-BENEFIT EVALUATION BY A COMMITTEE SELECTED BY THE COMMISSION. SUCH COMMITTEE SHALL CONSIST OF TWO REPRESENTATIVES FROM THE STATE DEPARTMENT OF TRANSPORTATION, TWO INDIVIDUALS FROM THE ASPHALT PAVING CONSTRUCTION INDUSTRY, AND AN INDEPENDENT ENGINEER WHO SHALL BE COMPENSATED BY THE DEPARTMENT FOR REASONABLE FEES. COMMITTEE MEMBERS SHALL NOT BE CONNECTED WITH THE PAVEMENT PROJECT THAT IS THE SUBJECT OF SUCH COST-BENEFIT EVALUATION. SAID COMMITTEE SHALL GATHER DATA ON ACTUAL COSTS, INCLUDING MAINTENANCE COSTS, OF WARRANTED PROJECTS AND COMPARABLE NONWARRANTED PROJECTS, AND PRESENT ITS CONCLUSIONS IN A REPORT TO THE HOUSE AND SENATE TRANSPORTATION COMMITTEES AT THE END OF THE WARRANTY PERIOD FOR THE PROJECTS OR AT AN EARLIER DATE SPECIFIED BY EITHER COMMITTEE.

SECTION 2. Effective date. This act shall take effect at 12:01 a.m. on the day following the expiration of the ninety-day period after final adjournment of the general assembly that is allowed for submitting a referendum petition pursuant to article V, section 1 (3) of the state

constitution; except that, if a referendum petition is filed against this act or an item, section, or part of this act within such period, then the act, item, section, or part, if approved by the people, shall take effect on the date of the official declaration of the vote thereon by proclamation of the governor.

Tom Norton
PRESIDENT OF
THE SENATE

Charles E. Berry
SPEAKER OF THE HOUSE
OF REPRESENTATIVES

Joan M. Albi
SECRETARY OF
THE SENATE

Judith M. Rodrigue
CHIEF CLERK OF THE HOUSE
OF REPRESENTATIVES

APPROVED May 21, 1997 at 7:51 p.m.

Roy Romer
GOVERNOR OF THE STATE OF COLORADO

APPENDIX B: FHWA APPROVAL LETTER

U.S. Department
of Transportation
Federal Highway
Administration

Colorado Federal Aid Division
555 Zang Street, Room 250
Lakewood, Colorado 80228

November 8, 1999

In Reply Refer To:
HDA-CO

Mr. Thomas E. Norton
Executive Director
Colorado Department of Transportation
4201 E. Arkansas Avenue
Denver, Colorado 80222

Re: Hot Bituminous Pavement
(HBP) Warranty Specification

Attn: Mr. William F. Reisbeck
Chief Engineer

Dear Mr. Norton:

We have reviewed the proposed HBP Warranty Specification for application on National Highway System projects in Colorado, which was provided to this office on November 5, 1999. The associated revised specifications and project selection guidelines were extremely helpful in determining the adequacy of this specification.

We commend your staff on the insight and planning which has been incorporated into the document titled *Pavement Warranty Provisions: CDOT 's Future Direction.* Your strategic direction for implementation of pavement warranties using the defined steps should provide a balanced level of risk for CDOT and the hot mix industry as the various pavement warranties are introduced. Successful use of pavement warranties in Colorado will place CDOT and your industry partners as national leaders in the expanding scope of asset management.

The revised Section 403 specification and the associated revised specifications are adequate for implementation in pilot projects which will be advertised in CDOT Fiscal Year 2000. The proposed revision of Section 403, Warranted Hot Bituminous Pavement Specification, dated November 8, 1999, is approved for limited use on NHS projects in Colorado.

Please provide this office notice of each of the pilot projects that is let to bid using this specification so that we can track implementation.

Please address any future correspondence or revisions to pavement warranty specifications to Mr. Bernie Kuta, of this office, at 303-969-6730, Ext. 382.

Sincerely yours,

James Daves
Division Administrator

cc: John M. Umbewust, Deputy Chief Engineer, CDOT
Steve W. Horton, Design Construction Engineer, CDOT
Tim Aschenbrener, Materials Engineer, CDOT
Richard Zamora, Pavement Design/Management Engineer

APPENDIX C: HMA WARRANTY SPECIFICATION USED FOR 1998 PROJECTS

REVISION OF SECTION 403
WARRANTED HOT BITUMINOUS PAVEMENT

Section 403 of the Standard Specifications is hereby revised for this project to include the following:

DESCRIPTION

This work consists of the construction of warranted bituminous pavement in accordance with these specifications, and in conformity with the lines and grades shown on the plans or established.

MATERIALS AND CONSTRUCTION REQUIREMENTS

The provisions of Section 401 do not apply to warranted hot bituminous pavement.

The Contractor shall be responsible for the bituminous pavement mix design, production, placement, Performance, process and thickness control testing, and warranty work for a period of three years from the date of pavement acceptance.

The warranted bituminous pavement shall be a mixture of aggregate, filler or additives if used, bituminous material, hydrated lime, and reclaimed material if used. A minimum of one per cent hydrated lime by mass of the combined aggregate shall be added to the aggregate for all warranted bituminous pavement.

The Contractor shall establish the materials mix design (MMD) for the bituminous pavement. The MMD consists of an aggregate gradation based on percentages of the material passing various sieve sizes, a percentage by mass of bituminous material to be added to the aggregate, and a temperature for the mixture at discharge from the mixing plant. The Contractor shall select all materials to be used in the mixture including the asphalt cement. Transverse cracking shall not be included in the performance warranty if the asphalt cement meets or exceeds the low temperature required for Superpave performance grade PG 76-28 conforming to subsection 702.0 1.

The minimum thickness structural design shall be as shown on the plans. The Contractor shall submit to the Engineer with the MMD, details of any proposed increases in thickness.

Two weeks before starting paving, the Contractor shall provide the Engineer the MMD, the method of developing the MMD, all MMD testing, a list of materials, all thickness testing methods, and all Proposed thicknesses.

The bituminous pavement shall be warranted for three years against the types of distress listed in (d) below.

(a) Warranty and Warranty Bond. By submission of its bid in response to this specification, the Contractor warrants that all of the bituminous pavement placed on the project shall be free of defective materials and workmanship for a period of three years from the date of pavement acceptance.

The Contractor further warrants that if any defect occurs in the bituminous pavement materials or workmanship within that three year period and if that warranty work is required or needed on that pavement, then the Contractor will ensure proper and prompt performance and completion of that warranty work, including payments for all labor performed and for all equipment and materials used, in accordance with this specification.

The Contractor understands and further warrants that if so required by the Department the Contractor shall perform and complete that warranty work after that three year period has ended because the Department needs the warranty work performed at that later date due to weather delays or other project related reasons that do not reasonably allow that work to be performed during the three year period, provided that the start of any such performance shall not be required later than nine months after that three year period has ended,

The Contractor further agrees that the three year warranty period described in the specification shall be deemed to be extended by this additional nine months for the purposes described above, and Contractor warrants to perform that warranty work within that additional nine months if so required by the Department.

All such warranty work shall be at the Contractor's sole cost and expense.

The Contractor shall provide a warranty performance bond ("warranty bond") to guarantee the full performance of the warranty work described in this specification. The warranty bond shall be in the amount of $825,000.

The warranty bond shall be a single term three year (plus an additional nine months in certain circumstances) warranty bond that will be in effect for the entire warranty period. The warranty bond shall be in effect upon pavement acceptance, and it shall remain in effect for the total of three years from that date. The Contractor shall provide a three year warranty bond, that complies with this specification, to CDOT at the time of execution of the Contract.

The need for warranty work, and the performance of that warranty work, shall be determined in accordance with (d) below. At the end of the warranty period, the Contractor will be released from further warranty work or responsibility, provided all required warranty work has been satisfactorily completed-

(b) Pavement Evaluation Team (PET). The PET shall have the final decision authority for all warranty work. The PET shall consist of three subject matter experts not affiliated with the project. Two members shall be selected by the Chief Engineer and directly paid by the Department.

One member will be a CDOT staff person, the other will be a private consultant. The third member will represent the asphalt paving industry.

Members will be replaced as necessary based upon the criteria above.

(c) Warranty Work. During the warranty period the warranty work shall be performed at no cost to the Department and shall be based on the results of the pavement distress survey. Warranty work to be performed and materials to be used shall be in accordance with the remedial actions and other requirements in (d). The Contractor may propose alternative actions for warranty work to the Engineer who will submit the proposal to the PET. All warranty work to repair distresses shall be done in accordance with current CDOT standards and coordinated with the Engineer. Innovative materials and techniques may be considered. The PET will render a final decision by a majority vote.

During the warranty period, the Contractor may monitor the pavement in question using nondestructive procedures. All proposed remedial actions shall be coordinated with the Engineer.

Coring, milling or other destructive procedures shall not be performed by the Contractor without prior written consent of the Engineer. The Contractor is not responsible for damages that are a result of Coring, miffing or other destructive procedures conducted by the Department, utility companies or other entities not under the control of the Contractor.

When notified by the PET that warranty work is required, the Engineer will notify the Contractor and Surety, in writing. If the Contractor or Surety fails to undertake repair work within fifteen days after receiving written notice from the Engineer, the CDOT may make repairs or contract to have the repairs and the Contractor and surety shall be responsible for the total cost of these repairs including lane rental fees.

At least 30 days before the expiration of the warranty the PET shall conduct a pavement distress survey. If the Engineer is notified by the PET that warranty work is required in accordance with the distress indicators, the Engineer will notify the Contractor and surety in writing. If the Contractor or the Surety fails to undertake repair work within 15 days after receiving written notice from the Engineer, CDOT will complete the repairs or contract to have the repairs completed and the Contractor and Surety shall be responsible for the total cost of these repairs including the lane rental fees.

Warranty work that requires a resurfacing of the pavement shall not be performed later than the first day of October of any year. If warranty work is halted or not begun by this date, the work shall resume the first day of April of the next year. Warranty work shall not be performed during wet weather and shall be performed to the same standards as the initial construction.

The Engineer may choose to delay the warranty work due to unfavorable seasonal restrictions or other reasons deemed to be in the public interest.

The Contractor shall pay a daily lane rental fee for the closure of each lane within the project during the warranty work, including elective and preventive action. Tins fee will be assessed for each calendar day or portion thereof, during the warranty work, that the traffic is limited to less than the number of lanes in the final configuration as shown in the construction plans. The Contractor shall maintain traffic at all times as detailed in the Traffic Control Plan. Warranty work shall be performed during the times of day and days of week specified for the original contract work.

The Contractor and surety shall be responsible for the lane rental fee. The fee will be based on the applicable rates for any and all closures whether work is performed or not. This fee is not a penalty, but is a rental fee based upon road user cost to occupy lanes.

The lane rental fee for this project after pavement acceptance shall be $2,000 per day, if the warranty work is going to be performed during hours of 6:00 am. to 7:00 pm. During night time warranty work between 7:00 p.m. and 6-00 a.m. the lane rental charge shall be $500 per day.

(d) Pavement Distress Indicators, Thresholds and Remedial Action. Pavement distress indicators shown below shall be used as the basis for determining the distress types to be considered for repair under the warranty and as the basis for determining the methods for measuring distresses.

The Pavement distress surveys are conducted by dividing the roadway into nominal one-kilometer sections. A 100 in segment in each kilometer will be evaluated for pavement distress. The segment evaluated shall be from 300 to 400 in from the start of the section. In addition, in each section, a random 100 m segment will be surveyed. The random 100 m segments will be determined by the PET each time a survey is conducted.

The PET will conduct an annual survey or a survey at any other time if requested in writing by the Engineer. The PET will notify the Engineer in writing of the survey results within 14 days. The Engineer will immediately notify the Contractor.

If the survey requires remedial action and the Contractor does not dispute the survey results, the Contractor shall remedy the distress. If the survey requires remedial action and the Contractor disputes the survey results, the Contractor shall notify the Engineer in writing within 14 days of receiving notice. The notification shall describe the contractual and legal basis for the disagreement with the survey results. The Engineer will transmit the Contractor's notification to the PET which will render a final decision and notify the Engineer in writing within 30 days of the Contractor's notification.

The PET shall determine the remedial action to be performed in all segments in the project where the threshold level is met or exceeded. If arm outside the. survey segments are suspected of meeting or exceeding a threshold level, the Department will divide the entire project into 100 in segments and conduct the distress survey in any, or all, segments to see if a threshold level has been met or exceeded. Unless otherwise directed by the Engineer remedial action shall be performed in the same calendar year as the survey that indicated the threshold level is met or exceeded Remedial action shall be applied to each entire segment in which the threshold level is met or exceeded unless otherwise noted under remedial action. If, anytime during the warranty period, 30 percent or more of the project segments require or have received remedial action, then the entire project shall receive a remedial action as determined by the PET. Remedial action required on the mainline roadway shall also be performed on the bituminous pavement shoulders and adjacent lanes.

If remedial action necessitates a corrective action to the pavement markings, adjacent lanes or roadway shoulders, then such corrective action to the pavement markings, adjacent lanes and shoulders shall be performed at the expense of the Contractor.

When remedial action requires the removal of pavement, the pavement shall be replaced with a mix approved by the PET. The mix shall be placed according to the Contractor's QCP. Pavement shall be removed by cutting neat lines vertically for the full depth of the affected layer unless otherwise specified. Removal areas shall be rectangular, and the sides and bottoms shall be thoroughly coated with an approved tack coat prior to pavement replacement.

REVISION OF SECTION 403
WARRANTED HOT BITUMINOUS PAVEMENT

The Contractor will not be held responsible for distresses which are caused by factors beyond the control of the Contractor. A finding that the distress is due to factors outside the control of the Contractor shall be based on evidence submitted by the Contractor to the Engineer. The PET will make the final determination.

Distress types to be warranted, the threshold levels requiring remedial action, and the remedial action to be performed by the Contractor shall be according to the following pavement distress indicators:

1. *Permanent Deformation -Rutting and Shoving.* Rutting is longitudinal surface depression in the wheel path. Shoving is longitudinal displacement of a localized area of the pavement surface caused by traffic pushing against the pavement.

   Remedial action for permanent deformation > 8 min in depth: affected area shall be milled to remove ruts or shoved areas and replaced.

The Permanent Deformation - Correction of rutting and shoving will not be required when the accumulated Equivalent Single Axle Loads (ESAL's) exceed "w" at time intervals shown below:

Time after Pavement Acceptance (sampling intervals)	Maximum Accumulated ESAL's (where D=3 year projection in ESAL's) "w"
6 months	0.25 x D
12 months	0.50 x D
18 months	0.75 x D
24 months	D
30 months	1.25 x D
36 months (full term)	1.50 x D

If the rutting is suspected to be caused by the base or subgrade, coring (or cross sectional sampling) will be conducted by CDOT to determine the cause of the rutting.

2. *Pot Holes.* Pot holes are bowl shaped depressions of various sizes in the pavement surface caused by loss of pavement mix.

   Remedial action for potholes > 6 min deep and >0.1 in area: affected area shall be repaired by removal and replacement to 600 min beyond the apparent distress.

3. *Longitudinal* Joint Separation. Longitudinal Joint Separation is loss of the pavement surface or depressions near a longitudinal joint.

   Remedial Action for longitudinal joint separation > 13 min deep: affected area shall be removed and replaced 150 min beyond the distress laterally and to two feet beyond the distress longitudinally-

4. *Raveling and Weathering.* Raveling and weathering are the wearing away of the pavement surface caused by the dislodging of aggregate particles (raveling) and the loss of asphalt binder (weathering).

Remedial action for raveling and weathering > 6 mm deep and > 0. 1 m2 in area: affected area shall be removed and replaced to 600 mm. beyond the apparent distress.

5. *Bleeding.* Bleeding is a film of bituminous material on the pavement surface which creates a shiny, glass-like, reflective surface.

Severity	Quantity	Remedial Action Required
LOW	Coloring of surface visible	Observe more frequently
Moderate to High	Asphalt free on surface	Remove and replace full width of lane or shoulder to two feet longitudinally beyond affected area.

6. *Delamination of Pavement Layers.* Delamination of pavement is the separation of one layer from the layer below it.

Remedial action for delamination: affected area shall be removed and replaced to 300 mm beyond the apparent distress.

7. *Transverse Cracking.* Transverse cracks are cracks relatively perpendicular to the pavement centerline. The highest severity level present for at least 10% of the total length of the crack shall be assigned. Random cracks with transverse cracks are cracks that occur randomly and are within 600 mm of the transverse crack. Spalling with transverse cracks is the cracking, breaking or chipping of the pavement surface within *600* mm of the transverse crack

Severity	Quantity	Action Required
LOW Moderate	< 6 mm wide < 19 mm wide < 6 mm wide with spalling or random cracking	Seal cracks with hot poured joint and crack sealant materials that meet the requirements of ASTM D 3405.
High	> 19 mm wide < 19 mm wide with spalling and random cracking	Remove and replace full width of lane or shoulder to one foot longitudinally beyond the apparent distress.

(e) Elective or Preventive Action. The Contractor or Surety shall submit a written proposal to the Engineer if it proposes to perform elective or preventive work. The Engineer will forward the proposal to the PET for a final decision. Elective or Preventive action shall be a Contractor or Surety option subject to the approval of the Engineer. Elective or Preventive work shall be done during times set forth in the Contract for original contract work. Lane rental fees will be assessed.

(f) Emergency work. The Engineer may request immediate action of the Contractor and Surety for the safety of the traveling public. The Contractor or Surety shall have the first option to perform the emergency work. If the Contractor or Surety cannot perform the emergency work within 24 hours, the Engineer may have the emergency work done by other forces and seek reimbursement from the Contractor or Surety accordingly. Emergency work performed by other forces shall not alter the requirements, responsibilities, or obligations of the warranty.

(g) Traffic Control. Construction Traffic control for warranty work shall be performed in accordance with Section 630 at the Contractor's expense.

(h) Process Control Testing. The Contractor shall perform process control testing in accordance with the Revision of Section 106, Quality Control for Warranted Hot-Bituminous Pavement.

METHOD OF MEASUREMENT

Warranted bituminous pavement will be measured for payment by the ton of mixture based on the quantity of mixture placed, completed and accepted. The Contractor shall present certified records of shipment for the quantities placed under this special provision.

BASIS OF PAYMENT

Warranted bituminous pavement, measured as provided above, will be paid for at the contract unit price per ton of mixture, which price will be full compensation for furnishing, preparing, hauling, mixing and placing all materials, including asphaltic materials, for compacting mixtures, for the warranty and warranty bonds, for
* warranty work, for the materials mix design, for the Quality Control Plan, for testing, record keeping, sampling, and for all labor, tools, and equipment during construction and during the warranty period, and incidentals necessary to complete the work. Payment will be made under:

Pay Item	**Pay Unit**
Hot Bituminous Pavement (Asphalt)(3 Year Warranty)	Ton

The pay quantity shall be the actual quantity of warranted bituminous pavement placed, not to exceed 105 % of plan quantity.

Water used in the mixing plant to bring the lime-aggregate mixture to approved moisture content will not be measured and paid for separately but shall be included in the work.

Facilities for testing hot bituminous plant mix at the site of the commercial plant will not be paid for separately, but shall be included in the work.

APPENDIX D: HMA WARRANTY SPECIFICATION USED FOR 2000 AND 2001 PROJECTS

REVISION OF SECTION 106
QUALITY CONTROL FOR
WARRANTED HOT BITUMINOUS PAVEMENT

Section 106 of the Standard Specifications is hereby revised for this project as follows:

Add subsection 106.09 as follows:

106.09 Quality Control For Warranted Hot Bituminous Pavement. Quality Control (QC) is the responsibility of the Contractor. The Contractor shall establish and maintain all necessary inspection and materials testing procedures to assure the quality of work and the completed pavement.
The Contractor's QC Manager is responsible for compliance with the quality requirements specified in the Contract and the Contractor's approved QC plan (QCP). The QC Manager shall not be the Contractor's Superintendent.
The Contractor shall make provisions such that the Engineer can inspect QC work in progress, including sampling, testing, plants, and the Contractor's testing facilities at any time.

(a) **Quality Control Plan (QCP).** The Contractor shall submit a written QCP to the Engineer at least two weeks prior to the beginning of work that is controlled by the QCP. The QCP shall list all inspection and materials testing procedures utilized by the Contractor to ensure that the work conforms to contract requirements.

The QCP shall address the following:

(1) The name, qualifications, duties, responsibilities and authorities of each person assigned a QC function.

The QC Manager shall be the person responsible for the process control sampling and testing. This person must possess at least one of the following qualifications:

A. Registration as a Professional Engineer in the State of Colorado.
B. Level II A, B, and C certifications from the Laboratory Certification for Asphalt Technicians (LabCAT).

Technician Qualifications. Technicians taking samples and performing tests must possess the following qualifications:

A. Technicians taking samples and conducting compaction tests must have Level II A certification from the Laboratory Certification for Asphalt Technicians (LabCAT).
B. Technicians conducting process control tests must have Level II B certification from the Laboratory Certification for Asphalt Technicians (LabCAT).
C. Technicians determining asphalt mixture volumetrics and strength characteristics must have Level II C certification from the Laboratory Certification for Asphalt Technicians (LabCAT).

(2) A description of the responsibilities and authority, and a resume of experience, of the QC Manager.
(3) Materials testing schedule, showing sampling and testing procedures and frequencies.
(4) The standards to which the pavement is to be constructed, such as: in place density, asphalt content, voids criteria, gradation, or all other criterion the Contractor intends to use to maintain the quality of the work.
(5) Reporting procedures, including proposed reporting formats for materials sampling, testing, and inspection for all phases of the work.
(6) Names of testing and engineering firms to be used, if any, with licenses as appropriate.
(7) Procedures for identifying, evaluating, and reporting non-conformance discovered during QC inspections and testing.

(8) Provisions for increased frequencies of inspection and testing when work does not conform to the standards set for the construction.

(b) **Documentation.** The Contractor shall maintain current records of quality control operations activities, and tests performed including the work of vendors and subcontractors. These records shall be in the form shown in the QCP and shall indicate, as a minimum, the subcontractor, if any, the number of personnel working, the weather conditions encountered, any delays encountered, locations corresponding to project stationing as shown on the plans, and acknowledgment of deficiencies noted along with the corrective actions taken on deficiencies. These records shall include factual evidence that required activities or tests have been performed, including but not limited to the following:

(1) Type and number of quality control activities and tests involved.
(2) Results of quality control activities or tests.
(3) Nature of defects, causes for rejection, etc.
(4) Proposed remedial action.
(5) Corrective actions taken.

Such records shall cover both conforming and defective or deficient features and shall include a statement that work and materials incorporated in the project comply with this Contract. Copies of these records shall be reviewed by the QC Manager and submitted to the Engineer prior to payment for the work.

(c) **Frequency.** QC inspection and testing at all intervals of work shall be performed at the frequencies in the accepted QCP.

(d) **Certification.** Prior to acceptance of the project, the Contractor's QC Manager shall certify, in writing, that all work and materials incorporated into the project meet the requirements of the Contract.

REVISION OF SECTION 403
WARRANTED HOT BITUMINOUS PAVEMENT

Section 403 of the Standard Specifications is hereby revised for this project to include the following:

DESCRIPTION

This work consists of the construction of warranted bituminous pavement in accordance with these specifications, and in conformity with the lines and grades shown on the plans or established.

MATERIALS AND CONSTRUCTION REQUIREMENTS

The provisions of Section 401 do not apply to warranted hot bituminous pavement except for the following: Longitudinal joints shall conform to the requirements of subsection 401.16. Roadway smoothness shall conform to the requirements of subsection 401.20 as revised in the *Revision of Sections 105, 202, 401, 405, 406, and 412 - Roadway Smoothness*. Paving limitations shall conform to the requirements of subsection 401.07 as revised in the *Revision of Section 401 – Weather Limitations and Placement Temperatures.*

The Contractor shall be responsible for the bituminous pavement mix design, production, placement, performance, process and thickness control testing, and warranty work for a period of ___**years from the date of pavement acceptance.

The warranted bituminous pavement shall be a mixture of aggregate, filler or additives if used, bituminous material, hydrated lime, and reclaimed material if used. A minimum of one percent hydrated lime by weight of the combined aggregate shall be added to the aggregate for all warranted bituminous pavement.

The Contractor shall establish the materials mix design (MMD) for the bituminous pavement. The MMD consists of an aggregate gradation based on percentages of the material passing various sieve sizes, a percentage by weight of bituminous material to be added to the aggregate, and a temperature for the mixture at discharge from the mixing plant. The Contractor shall select all materials to be used in the mixture including the asphalt cement. Transverse cracking shall not be included in the performance warranty if the asphalt cement meets or exceeds the low temperature required for Superpave performance grade PG _____conforming to subsection 702.01.

The minimum thickness placed shall be as shown on the plans.

Two weeks before starting paving, the Contractor shall provide the Engineer the MMD, the method of developing the MMD, all MMD testing, a list of materials, and all thickness testing methods.

The bituminous pavement shall be warranted for ___**years against the types of distress listed in (d) below.

(a) **Warranty and Warranty Bond.** By submission of its bid in response to this specification, the Contractor warrants that all of the bituminous pavement placed on the project shall be free of defective materials and workmanship for a period of ___** years from the date of pavement acceptance as defined in the Revision of 105.16 Acceptance.

The Contractor further warrants that it will ensure proper and prompt performance and completion of warranty work in accordance with this specification. Warranty work shall be performed when any defect occurs in the bituminous pavement materials or workmanship within that ___** year period and warranty work is required or needed on that pavement. Prompt performance and completion of warranty work includes payment for all labor performed and for all equipment and materials used.

The Contractor understands and agrees that if so required by the Department, the Contractor shall perform and complete warranty work after the ___** year period has ended. Delays for warranty work can and may occur due to factors such as weather delays, project reasons which do not reasonably allow that work to be performed, public interest reasons or for any other reason. Performance due to delays will not be required to start later than nine months after the ___** year period has ended.

All such warranty work shall be solely at the Contractor's expense up to $____##. The Department may elect to have additional work performed and will be responsible for payment of actual expenses incurred by the Contractor. Additional work shall be authorized in writing by the Engineer. All documentation of actual costs incurred in the performance of warranty work shall be made available for audit by the Department.

The Contractor shall provide a warranty performance bond ("warranty bond") to guarantee the full performance of the warranty work described in this specification. The warranty bond shall be in the amount of $_____##

The warranty bond shall be a single term ___** year (plus an additional nine months in certain circumstances) warranty bond that will be in effect for the entire warranty period. The warranty bond shall be in effect upon pavement acceptance, and it shall remain in effect for the total of ___** years from that date. The Contractor shall provide a ___** year warranty bond, that fully complies with this specification, to the Department at the time of execution of the Contract.

The need for warranty work, and the performance of that warranty work, shall be determined in accordance with (d) below. The Contractor will be released from further warranty work at the end of the warranty period or upon completion of any delay warranty work, as described above, whichever is later, provided all required warranty work has been satisfactorily completed.

(b) **Pavement Evaluation Team (PET).** The PET shall have the final decision authority for all warranty work. The PET shall consist of three subject matter experts not affiliated with the project. One member will be a CDOT staff person, the second member will represent the asphalt paving industry, and the third will be mutually agreed upon by the other two members. Each member of the PET shall have a minimum 15 years experience in one or a combination of the following disciplines: pavement management, asphalt pavement design, asphalt pavement construction, maintenance management or asphalt pavement maintenance. CDOT will cover expenses associated with performing the duties of the PET for the CDOT member and the mutually agreed upon third party. The Contractor shall cover expenses associated with performing the duties of the PET for the asphalt paving industry member Members will be replaced as necessary based upon the criteria above.

The Department representative on the PET shall be responsible for scheduling distress surveys, preparing the reports, and notifying the Engineer when warranty work is required.

(c) **Warranty Work.** During the warranty period the warranty work shall be performed at no cost to the Department and shall be based on the results of the pavement distress survey. Warranty work to be performed and materials to be used shall be in accordance with the remedial actions and other requirements in (d). The Contractor may propose alternative actions for warranty work to the Engineer who will submit the proposal to the PET. All warranty work to repair distresses shall be done in accordance with current CDOT standards and coordinated with the Engineer. Innovative materials and techniques may be considered. The PET will render a final decision by majority vote.

During the warranty period, the Contractor may monitor the pavement in question using nondestructive procedures. All proposed remedial actions shall be coordinated with the Engineer. Coring, milling or other destructive procedures shall not be performed by the Contractor without prior written consent of the Engineer. The Contractor is not responsible for damages that are a result of coring, milling or other destructive procedures conducted by the Department, utility companies or other entities not under the control of the Contractor.

When notified by the PET that warranty work is required, the Engineer will notify the Contractor and Surety, in writing. If the Contractor or Surety fails to respond in writing within fifteen days after receiving written notice from the Engineer, the Department may make repairs or contract to have the repairs made and the Contractor and surety shall be responsible for the total cost of these repairs including lane rental fees.

At least 30 days before the expiration of the warranty the PET shall conduct a pavement distress survey. If the Engineer is notified by the PET that warranty work is required in accordance with the distress indicators, the Engineer will notify the Contractor and surety in writing. If the Contractor or the Surety fails to respond in writing within 15 days after receiving written notice from the Engineer, the Department will complete the repairs or contract to have the repairs completed and the Contractor and Surety shall be responsible for the total cost of these repairs including the lane rental fees. In the event it is necessary to delay performance of the final warranty work due to weather limitations or other reasons in the public interest, the Contractor and Department shall agree to the extent of work to be performed. Any additional distress resulting from the delay will be the responsibility of the Department.

Warranty work that requires a resurfacing of the pavement shall only be performed when weather conditions are in accordance with revised subsection 401.07.

A daily lane rental fee shall be charged for the closure of each lane within the project during the performance of warranty work, including elective and preventive action. This fee will be assessed for each calendar day or portion thereof, during the warranty work, that the traffic is limited to less than the number of lanes in the final configuration as shown in the construction plans. The fee will be based on the applicable rates for any and all closures whether work is performed or not. This fee is not a penalty, but is a rental fee based upon road user cost to occupy lanes.

REVISION OF SECTION 403
WARRANTED HOT BITUMINOUS PAVEMENT

The lane rental fee for this project after pavement acceptance shall be _____ per day

The Contractor shall maintain traffic at all times as detailed in the Traffic Control Plan. Warranty work shall be performed during the times of day and days of week specified for the original contract work.

(d) **Pavement Distress Indicators, Thresholds and Remedial Action.** Pavement distress indicators shown below shall be used as the basis for determining the distress types to be considered for repair under the warranty and as the basis for determining the methods for measuring distresses.

The pavement distress surveys are conducted by dividing the roadway into nominal one-mile sections. A one-tenth mile segment in each mile will be evaluated for pavement distress. The segment evaluated shall be from 0.3 to 0.4 miles from the start of the section. In addition, in each section, a random one-tenth mile segment will
be surveyed. The random one-tenth mile segments will be determined by the PET each time a survey is conducted.

The PET will conduct an intermediate survey(s) if requested in writing by the Engineer**.** The PET will notify the Engineer in writing of the survey results within 15 days. The Engineer will immediately notify the Contractor in writing. Traffic control for conducting the surveys will be the responsibility of the Department.

If any survey requires remedial action and the Contractor does not dispute the survey results, the Contractor shall remedy the distress. If the survey requires remedial action and the Contractor disputes the survey results, the Contractor shall notify the Engineer in writing within 15 days of receiving notice. The notification shall describe the contractual and legal basis for the disagreement with the survey results. The Engineer will transmit the Contractor's notification to the PET which will render a final decision and notify the Engineer in writing within 30 days of the Contractor's notification.

The PET shall determine the remedial action to be performed in all segments in the project where the threshold level is met or exceeded. If areas outside the survey segments are suspected of meeting or exceeding a threshold level, the PET will divide the entire project into 0.1 mile segments and conduct the distress survey in any, or all, segments to see if a threshold level has been met or exceeded**.** Unless otherwise directed by the Engineer remedial action shall be performed in the same calendar year as the survey that indicated the threshold level is met or exceeded. Remedial action shall be applied to each entire segment in which the threshold level is met or exceeded unless otherwise noted under remedial action. When the remedial action required includes an overlay, the action shall also be performed on the bituminous pavement shoulders and adjacent lanes.

If remedial action necessitates a corrective action to the pavement markings, adjacent lanes or roadway shoulders, then such corrective action to the pavement markings, adjacent lanes and shoulders shall be performed at the expense of the Contractor.

REVISION OF SECTION 403
WARRANTED HOT BITUMINOUS PAVEMENT

When remedial action requires the removal of pavement, the pavement shall be replaced with a mix approved by the PET. The mix shall be placed according to the Contractor's QCP. Pavement shall be removed by cutting neat lines vertically for the full depth of the affected layer unless otherwise specified. Removal areas shall be rectangular, and the sides and bottoms shall be thoroughly coated with an approved tack coat prior to pavement replacement.

If, anytime during the warranty period, 30 percent or more of the project segments require or have received remedial action, then the entire project shall receive a remedial action as determined by the PET.

The Contractor will not be held responsible for distresses which are caused by factors beyond the control of the Contractor. A finding that the distress is due to factors outside the control of the Contractor shall be based on evidence submitted by the Contractor to the Engineer. The PET will make the final determination.

Distress types to be warranted, the threshold levels requiring remedial action, and the remedial action to be performed by the Contractor shall be according to the following pavement distress indicators:

1. *Permanent Deformation - Rutting and Shoving.* Rutting is longitudinal surface depression in the wheel path. Shoving is longitudinal displacement of a localized area of the pavement surface caused by traffic pushing against the pavement. Rutting shall be measured at 50 foot intervals using a 6 foot straight edge, and taking several measurements transversely across the pavement to determine the maximum rut depth. Rut depths shall be rounded to the nearest 0.10 inch.

Severity	Quantity	Preferred Actions (Actual action to be approved by PET)
Low	> 0.3 to 0.5 in.	Micromill or diamond grind to remove ruts, chip seal, microsurface or remove and replace.
Moderate	> 0.5 to 1 in.	Micromill or diamond grind to remove ruts then microsurface or remove and replace.
High	> 1 in.	Evaluate the cause and then remove and replace.

The Permanent Deformation - Correction of rutting and shoving will not be required when the accumulated design lane Equivalent Single Axle Loads (ESAL's) exceed "w" at time intervals shown below @@:

Table A: 3 year Warranty Rutting Rate of Loading Table

Time after Pavement Acceptance (sampling intervals)	Maximum Accumulated ESAL's (where D = 3 year projection design lane ESAL's) "w"
6 months	0.25 x D
12 months	0.50 x D
18 months	0.75 x D
24 months	D
30 months	1.25 x D
36 months (full term)	1.50 x D

Table B: 5 year Warranty Rutting Rate of Loading Table

Time after Pavement Acceptance (sampling intervals)	Maximum Accumulated ESAL's (where D = 5 year projection design lane ESAL's) "w"
6 months	0.2 x D
12 months	0.40 x D
18 months	0.60 x D
30months	D
42 months	1.40 x D
54 months	1.50 x D
60 months (full term)	1.50 x D

If the rutting is suspected to be caused by the base or subgrade, coring (or cross sectional sampling) will be conducted by the Department to determine the cause of the rutting. The Contractor shall have the option to obtain cores and cross-section samples at his own expense, including repair of the sampled areas, traffic control, and all lane rental fees.

2. *Pot Holes.* Pot holes are bowl shaped depressions of various sizes in the pavement surface caused by loss of pavement mix.

Severity	Quantity	Preferred Actions (Actual action to be approved by PET)
Low	< 1 in. deep and > 0.2 ft^2	Seal coat or crack / joint seal
Moderate	1 in. to 2 in. deep and > 0.2 ft^2	Patch
High	> 2 in. deep and > 0.2 ft^2	Remove and replace to 2 feet beyond apparent distress.

3. *Longitudinal Joint Separation.* Longitudinal joint separation is loss of the pavement surface or depressions within 18 inches of a longitudinal joint.

Severity	Quantity (Mean Width)	Preferred Actions (Actual action to be approved by PET)
Low	<= 0.25 in.	Seal cracks with hot poured joint and crack sealant materials that meet the requirements of ASTM D 3405.
Moderate	> 0.25 in. and <= 0.75 in.	Seal cracks with hot poured joint and crack sealant materials which meet the requirements of ASTM D 3405, ASTM D 5078 or ASTM D 5078 with 22% scrap rubber
High	> 0.75 in.	Remove and replace a minimum of 6 inches beyond distress laterally and 2 feet beyond distress longitudinally. In no instance shall resulting joints be placed in the wheel path.

4. R*aveling and Weathering***.** Raveling and weathering are the wearing away of the pavement surface caused by the dislodging of aggregate particles (raveling) and the loss of asphalt binder (weathering). Affected area shall be repaired to 24" beyond apparent distress. Preferred actions include slurry seal, chip seal, Novachip, ultra-thin overlay or remove and replace. The actual action shall be approved by the PET.

5. *Bleeding*. Bleeding is a film of bituminous material on the pavement surface which creates a shiny, glass-like, reflective surface.

Severity	Quantity	Preferred Actions (Actual action to be approved by PET)
Low	Coloring of surface visible	Observe more frequently
Moderate	Asphalt free on surface	Microsurface or SMA overlay
High	Asphalt free on surface and tire tracks	Remove and replace full width of lane or shoulder to two feet longitudinally beyond affected area.

6. *Delamination of Pavement Layers.* Delamination of pavement is the separation of one layer from the layer below it.

   Remedial action for delamination: affected area shall be removed and replaced to one foot beyond the apparent distress.

7. *Transverse Cracking*. Transverse cracks are cracks relatively perpendicular to the pavement centerline. The highest severity level present for at least 10% of the total length of the crack shall be assigned. Random cracks with transverse cracks are cracks that occur randomly and are within two feet of the
   transverse crack. Spalling with transverse cracks is the cracking, breaking or chipping of the pavement surface within two feet of the transverse crack.

Severity	Quantity	Preferred Action (actual action to be approved by PET)
Low	< 0.25 in. wide	Seal cracks with hot poured joint and crack sealant materials that meet the requirements of ASTM D 3405.
Moderate	< 0.75 in. wide < 0.25 in. wide with spalling or random cracking	Seal cracks with hot poured joint and crack sealant materials which meet the requirements of ASTM D 3405, ASTM D 5078 or ASTM D 5078 with 22% scrap rubber.
High	≥ 0.75 in. wide < 0.75 in. wide with spalling and random cracking	Remove and replace full width of lane or shoulder to one foot longitudinally beyond the apparent distress.

(e) **Elective or Preventive Action**. Elective or Preventive action shall be a Contractor or Surety option, at the Contractor or Surety expense, subject to the approval of the Engineer. The Contractor or Surety shall notify the Engineer in writing if it proposes to perform elective or preventive work. Elective or Preventive work shall be done during times set forth in the Contract for original contract work. Lane rental fees will be assessed.

(f) **Emergency Work.** For warranted distresses**,** the Engineer may request, in writing, immediate action of the Contractor and Surety for the safety of the traveling public. The Contractor or Surety shall have the first option to perform the emergency work. If the Contractor or Surety cannot perform the emergency work within 24 hours, the Engineer may have the emergency work done by other forces and

seek reimbursement from the Contractor or Surety accordingly. Emergency work performed by other forces shall not alter the requirements, responsibilities, or obligations of the warranty.

(g) **Traffic Control**. Construction Traffic control for warranty work shall be performed in accordance with Section 630 at the Contractor's expense.

(h) **Process Control Testing:** The Contractor shall perform process control testing in accordance with the Revision of Section 106, Quality Control for Warranted Hot Bituminous Pavement.

METHOD OF MEASUREMENT

Bituminous pavement will be measured for payment by the ton of mixture based on the quantity of mixture placed, completed and accepted. The Contractor shall present certified records of shipment for the quantities placed under this special provision.

BASIS OF PAYMENT

Warranted bituminous pavement, measured as provided above, will be paid for at the contract unit price per ton of mixture, which price will be full compensation for furnishing, preparing, hauling, mixing and placing all materials, including asphaltic materials, for compacting mixtures, for the materials mix design, for the Quality Control Plan, for testing, record keeping, sampling, and for all labor, tools, and equipment during construction and incidentals necessary to complete the work.

The Hot Bituminous Pavement Warranty will be paid at the contract unit price, which will be full compensation for the warranty and warranty bonds, for performing warranty work and for all materials, labor, tools and equipment used during performance of warranty work, and incidentals necessary to complete the warranty work.

Payment will be made under:

Pay Item	**Pay Unit**
Hot Bituminous Pavement (Asphalt) (__** Year Warranty)	Ton
*Hot Bituminous Pavement __** Year Warranty*	*Lump Sum*

Payment for the Hot Bituminous Pavement ___** Warranty will be made upon pavement acceptance.

Water used in the mixing plant to bring the lime-aggregate mixture to approved moisture content will not be measured and paid for separately but shall be included in the work.

Facilities for testing hot bituminous plant mix at the site of the commercial plant will not be paid for separately, but shall be included in the work.

****

INSTRUCTIONS TO DESIGNERS (delete instructions and symbols from final draft):

** Insert either 3 or 5 years, based upon project selection guidelines and specific project conditions. Delete this footnote.

Warranty bond amount will be calculated using 100% of the total for a 2" removal (planing), 2" overlay, complete restriping, plus 5% for traffic control and rounding up to the next highest $25,000. Delete footnote prior to use.

@@Use Table A for 3 year warranty and Table B for 5 year warranty and delete inappropriate table prior to use. Delete note prior to use

APPENDIX E: HMA WARRANTY SPECIFICATIONS FOR FIVE-YEAR WARRANTY PROJECTS

REVISION OF SECTION 105
ACCEPTANCE

Section 105 of the Standard Specifications is hereby revised for this project as follows:

Subsection 105.20(b), first paragraph shall include the following:

Final acceptance will occur upon the completion of the warranty period and all warranty work.

Subsection 105.20 shall include the following:

(c) *Pavement Acceptance.* Pavement acceptance will occur when the pavement surfaces are completely constructed, accepted for traffic, and determined by the Engineer to be in compliance with the contract plans and specifications. Pavement acceptance may occur on different dates for different parts of the pavement depending on varying acceptance dates for traffic or stage construction sequences.

(d) *Job Acceptance.* Job acceptance will occur upon the satisfactory completion of all work in the original bid schedule.

REVISION OF SECTION 106
QUALITY CONTROL FOR
WARRANTED HOT MIX ASPHALT

Section 106 of the Standard Specifications is hereby revised for this project as follows:

Add subsection 106.14 as follows:

106.14 Quality Control For Warranted Hot mix asphalt. Quality Control (QC) is the responsibility of the Contractor. The Contractor shall establish and maintain all necessary inspection and materials testing procedures to assure the quality of work and the completed pavement.

The Contractor's QC Manager is responsible for compliance with the quality requirements specified in the Contract and the Contractor's approved QC plan (QCP). The QC Manager shall not be the Contractor's Superintendent.

The Contractor shall make provisions such that the Engineer can inspect QC work in progress, including sampling, testing, plants, and the Contractor's testing facilities at any time.

(a) *Quality Control Plan (QCP).* The Contractor shall submit a written QCP to the Engineer at least two weeks prior to the beginning of work that is controlled by the QCP. The QCP shall list all inspection and materials testing procedures utilized by the Contractor to ensure that the work conforms to contract requirements.

The QCP shall address the following:

(1) The name, qualifications, duties, responsibilities and authorities of each person assigned a QC function.

The QC Manager shall be the person responsible for the process control sampling and testing. This person must possess at least one of the following qualifications:
(i) Registration as a Professional Engineer in the State of Colorado.
(ii) Level II A, B, and C certifications from the Laboratory Certification for Asphalt Technicians (LABCAT).

Technician Qualifications. Technicians taking samples and performing tests must possess the following qualifications:
(i) Technicians taking samples and conducting compaction tests must have Level II A certification from the Laboratory Certification for Asphalt Technicians (LABCAT).
(ii) Technicians conducting process control tests must have Level II B certification from the Laboratory Certification for Asphalt Technicians (LABCAT).
(iii) Technicians determining asphalt mixture volumetrics and strength characteristics must have Level II C certification from the Laboratory Certification for Asphalt Technicians (LABCAT).

(2) A description of the responsibilities and authority, and a resume of experience, of the QC Manager.
(3) Materials testing schedule, showing sampling and testing procedures and frequencies.
(4) The standards to which the pavement is to be constructed, such as: in place density, asphalt content, voids criteria, gradation, or all other criterion the Contractor intends to use to maintain the quality of the work.

(5) Reporting procedures, including proposed reporting formats for materials sampling, testing, and inspection for all phases of the work.
(6) Names of testing and engineering firms to be used, if any, with licenses as appropriate.
(7) Procedures for identifying, evaluating, and reporting non-conformance discovered during QC inspections and testing.
(8) Provisions for increased frequencies of inspection and testing when work does not conform to the standards set for the construction.

(b) *Documentation.* The Contractor shall maintain current records of quality control operations activities, and tests performed including the work of vendors and subcontractors. These records shall be in the form shown in the QCP and shall indicate, as a minimum, the subcontractor, if any, the number of personnel working, the weather conditions encountered, delays encountered, locations corresponding to project stationing as shown on the plans, and acknowledgment of deficiencies noted along with the corrective actions taken on deficiencies. These records shall include factual evidence that required activities or tests have been performed, including but not limited to the following:

(1) Type and number of quality control activities and tests involved.
(2) Results of quality control activities or tests.
(3) Nature of defects, causes for rejection, etc.
(4) Proposed remedial action.
(5) Corrective actions taken.

Such records shall cover both conforming and defective or deficient features and shall include a statement that work and materials incorporated in the project comply with this Contract. Copies of these records shall be reviewed by the QC Manager and submitted to the Engineer prior to payment for the work.

(c) *Frequency.* QC inspection and testing at all intervals of work shall be performed at the frequencies in the accepted QCP.

(d) *Certification.* Prior to acceptance of the project, the Contractor's QC Manager shall certify, in writing, that all work and materials incorporated into the project meet the requirements of the Contract.

REVISION OF SECTION 109
PARTIAL PAYMENTS

Section 109 of the Standard Specifications is hereby revised for this project as follows:

In subsection 109.06(a) delete the last sentence and replace with the following:

The amount retained will be in effect until such time as final payment is made, with the following exceptions which require the Contractor's written request and consent of the Surety: Upon completion and acceptance of the project, after the project quantities are finalized, and the Contractor has submitted the necessary forms, the Engineer may make reduction in the amount retained, or upon job acceptance a partial payment will be made that will include release of all retainage or securities.

REVISION OF SECTION 403
WARRANTED HOT BITUMINOUS PAVEMENT

Section 403 of the Standard Specifications is hereby revised for this project to include the following:

DESCRIPTION

This work consists of the construction of warranted bituminous pavement in accordance with these specifications, and in conformity with the lines and grades shown on the plans or established for the project.

MATERIALS AND CONSTRUCTION REQUIREMENTS

The provisions of Section 401 do not apply to warranted hot bituminous pavement of the project except the following Standard Special Provisions: Revision of Section 401-Longitudinal Joints and subsection 401.20 in the Revision of Sections 105, 202, 401, 405, 406, and 412-Roadway Smoothness.

The Contractor shall be responsible for the bituminous pavement mix design, production, placement, performance, process and thickness control testing, and warranty work for a period of five years from the date of pavement acceptance.

The warranted bituminous pavement shall be a mixture of aggregate, filler or additives if used, bituminous material, hydrated lime, and reclaimed material if used. A minimum of one per cent hydrated lime by mass of the combined aggregate shall be added to the aggregate for all warranted bituminous pavement.

The Contractor shall establish the materials mix design (MMD) for the bituminous pavement. The MMD consists of an aggregate gradation based on percentages of the material passing various sieve sizes, a percentage by mass of bituminous material to be added to the aggregate along with a temperature for the mixture at discharge from the mixing plant. The Contractor shall select all materials to be used in the mixture including the asphalt cement. Transverse cracking shall not be included in the performance warranty if the asphalt cement meets or exceeds the low temperature required for Superpave performance grade _____conforming to subsection 702.01.

The minimum thickness structural design shall be as shown on the plans. The Contractor shall submit to the Engineer with the MMD, details of any proposed increases in thickness.

Two weeks before starting paving, the Contractor shall provide the Engineer the MMD, the method of developing the MMD, all MMD testing, a list of materials, all thickness testing methods, all proposed thicknesses, and at least 60 pounds of plant produced material representing the MMD to CDOT for testing. The Bituminous Unit of CDOT will test the plant produced material in accordance to CPL 5112 “Hamburg Wheel Track Testing of Compacted Bituminous Mixtures” to ensure the Contractor is capable of producing material which will satisfy the warranty requirements. A maximum of 0.40 inches rut depth at a minimum 20,000 passes will be considered a passing test result for CPL 5112. The Contractor shall not commence paving before obtaining a mix design which satisfies the CPL 5112 performance criteria. If the material fails CPL 5112, the Contractor shall modify the MMD and re-submit at least 60 pounds of plant produced material representing the new MMD. The first test will be performed at no cost to the Contractor. Each re-test will be billed to the Contractor at the rate of $650.00 per test. Passing CPL 5112 test results shall not relieve the Contractor of any obligations under the warranty provisions.

REVISION OF SECTION 403
WARRANTED HOT BITUMINOUS PAVEMENT

The bituminous pavement shall be warranted for five years against the types of distress listed in (d) below.

(a) **Warranty and Warranty Bond.** By submission of its bid in response to this specification, the Contractor warrants that all of the bituminous pavement placed on the project shall be free of defective materials and workmanship for a period of five years from the date of pavement acceptance.

The Contractor further warrants that if any defect occurs in the bituminous pavement materials or workmanship within that five year period and if that warranty work is required or needed on that pavement, then the Contractor will ensure proper and prompt performance and completion of that warranty work, including payments for all labor performed and for all equipment and materials used, in accordance with this specification.

The Contractor understands and further warrants that if so required by the Department the Contractor shall perform and complete that warranty work after that five year period has ended because the Department needs the warranty work performed at that later date due to weather delays or other project related reasons that do not reasonably allow that work to be performed during the five year period, provided that the start of any such performance shall not be required later than nine months after that five year period has ended.

The Contractor further agrees that the five year warranty period described in the specification shall be deemed to be extended by this additional nine months for the purposes described above, and Contractor warrants to perform that warranty work within that additional nine months if so required by the Department.

All such warranty work shall be at the Contractor's sole cost and expense.

The Contractor shall provide a warranty performance bond ("warranty bond") to guarantee the full performance of the warranty work described in this specification. The warranty bond shall be in the amount of $ _____.

The warranty bond shall be a single term five year (plus an additional nine months in certain circumstances) warranty bond that will be in effect for the entire warranty period. The warranty bond shall be in effect upon pavement acceptance, and it shall remain in effect for the total of five years from that date. The Contractor shall provide a five year warranty bond, that fully complies with this specification, to CDOT at the time of execution of the Contract.

The need for warranty work, and the performance of that warranty work, shall be determined in accordance with (d) below. At the end of the warranty period, the Contractor will be released from further warranty work or responsibility, provided all required warranty work has been satisfactorily completed.

(b) **Pavement Evaluation Team (PET).** The PET shall have the final decision authority for all warranty work. The PET shall consist of three subject matter experts not affiliated with the project. Two members shall be selected by the Chief Engineer and directly paid by the Department.

One member will be a CDOT staff person, the other will be a private consultant. The third member will represent the asphalt paving industry.

Members will be replaced as necessary based upon the criteria above.

(c) **Warranty Work.** During the warranty period, the warranty work shall be performed at no cost to the Department and shall be based on the results of the pavement distress survey. Warranty work to be performed and materials to be used shall be in accordance with the remedial actions and other requirements in (d). The Contractor may propose alternative actions for warranty work to the Engineer who will submit the proposal to the PET. All warranty work to repair distresses shall be done in accordance with current CDOT standards and coordinated with the Engineer. Innovative materials and techniques may be considered. The PET will render a final decision by a majority vote.

During the warranty period, the Contractor may monitor the pavement in question using nondestructive procedures. All proposed remedial actions shall be coordinated with the Engineer. Coring, milling or other destructive procedures shall not be performed by the Contractor without prior written consent of the Engineer. The Contractor is not responsible for damages that are a result of coring, milling or other destructive procedures conducted by the Department, utility companies or other entities not under the control of the Contractor.

When notified by the PET that warranty work is required, the Engineer will notify the Contractor and Surety, in writing. If the Contractor or Surety fails to undertake repair work within 15 days after receiving written notice from the Engineer, the CDOT may make repairs or contract to have the repairs made and the Contractor and surety shall be responsible for the total cost of these repairs including lane rental fees.

At least 30 days before the expiration of the warranty the PET shall conduct a pavement distress survey. If the Engineer is notified by the PET that warranty work is required in accordance with the distress indicators, the Engineer will notify the Contractor and surety in writing. If the Contractor or the Surety fails to undertake repair work within 15 days after receiving written notice from the Engineer, the CDOT will complete the repairs or contract to have the repairs completed and the Contractor and Surety shall be responsible for the total cost of these repairs including the lane rental fees.

Warranty work that requires a resurfacing of the pavement shall not be performed later than October 1 of any year. If warranty work is halted or not begun by this date, the work shall resume March 1. Warranty work shall not be performed during wet weather and shall be performed to the same standards as the initial construction.

The Engineer may choose to delay the warranty work due to unfavorable seasonal restrictions or other reasons deemed to be in the public interest.

The Contractor shall pay a daily lane rental fee for the closure of each lane within the project during the warranty work, including elective and preventive action. This fee will be assessed for each

calendar day or portion thereof, during the warranty work, that the traffic is limited to less than the number of lanes in the final configuration as shown in the construction plans. The Contractor shall maintain traffic at all times as detailed in the Traffic Control Plan. Warranty work shall be performed during the times of day and days of week specified for the original contract work.

The Contractor and Surety shall be responsible for the lane rental fee. The fee will be based on the applicable rates for any and all closures whether work is performed or not. This fee is not a penalty, but is a rental fee based upon road user cost to occupy lanes.

The lane rental fee for this project after pavement acceptance shall be $_____ per day.

(d) **Pavement Distress Indicators, Thresholds and Remedial Action.** Pavement distress indicators shown below shall be used as the basis for determining the distress types to be considered for repair under the warranty and as the basis for determining the methods for measuring distresses.

The pavement distress surveys are conducted by dividing the roadway into nominal one-mile sections. A one-tenth mile segment in each mile will be evaluated for pavement distress. The segment evaluated shall be from 0.3 to 0.4 miles from the start of the section. In addition, in each section, a random one-tenth mile segment will be surveyed. The random one-tenth mile segments will be determined by the PET each time a survey is conducted.

The PET will conduct an annual survey or a survey at any other time if requested in writing by the Engineer**.** The PET will notify the Engineer in writing of the survey results within 14 days. The Engineer will immediately notify the Contractor.

If the survey requires remedial action and the Contractor does not dispute the survey results, the Contractor shall remedy the distress. If the survey requires remedial action and the Contractor disputes the survey results, the Contractor shall notify the Engineer in writing within 14 days of receiving notice. The notification shall describe the contractual and legal basis for the disagreement with the survey results. The Engineer will transmit the Contractor’s notification to the PET. The PET will render a final decision and notify the Engineer in writing within 30 days of the Contractor’s notification.

The PET shall determine the remedial action to be performed in all segments in the project where the threshold level is met or exceeded. If areas outside the survey segments are suspected of meeting or exceeding a threshold level, the Department will divide the entire project into tenth mile segments and conduct the distress survey in any, or all, segments to see if a threshold level has been met or exceeded**.** Unless otherwise directed by the Engineer remedial action shall be performed in the same calendar year as the survey that indicated the threshold level is met or exceeded. Remedial action shall be applied to each entire segment in which the threshold level is met or exceeded unless otherwise noted under remedial action. If, anytime during the warranty period, 30 percent or more of the project segments require or have received remedial action, then the entire project shall receive a remedial action as determined by the PET. Remedial action required on the mainline roadway shall also be performed on the bituminous pavement shoulders and adjacent lanes.

If remedial action necessitates a corrective action to the pavement markings, adjacent lanes or roadway shoulders, then such corrective action to the pavement markings, adjacent lanes and shoulders shall be performed at the expense of the Contractor.

When remedial action requires the removal of pavement, the pavement shall be replaced with a mix approved by the PET. The mix shall be placed according to the Contractor's QCP. Pavement shall be removed by cutting neat lines vertically for the full depth of the affected layer unless otherwise specified. Removal areas shall be rectangular, and the sides and bottoms shall be thoroughly coated with an approved tack coat prior to pavement replacement.

The Contractor will not be held responsible for distresses that are caused by factors beyond the control of the Contractor. A finding that the distress is due to factors outside the control of the Contractor shall be based on evidence submitted by the Contractor to the Engineer. The PET will make the final determination.

Distress types to be warranted, the threshold levels requiring remedial action, and the remedial action to be performed by the Contractor shall be according to the following pavement distress indicators:

1. *Permanent Deformation - Rutting and Shoving.* Rutting is longitudinal surface depression in the wheel path. Shoving is longitudinal displacement of a localized area of the pavement surface caused by traffic pushing against the pavement.

   Remedial action for permanent deformation > 0.31 inches in depth: affected area shall be milled to remove ruts or shoved areas and replaced.

   The Permanent Deformation - Correction of rutting and shoving will not be required when the accumulated Equivalent Single Axle Loads (ESAL's) exceed "w" at time intervals shown below:

Time after Pavement Acceptance (sampling intervals)	Maximum Accumulated ESAL's (where D = 5 year projection in ESAL's) "w"
6 months	0.20 x D
12 months	0.40 x D
18 months	0.60 x D
30 months	D
42 months	1.40 x D
54 months	1.50 x D
60 months (full term)	1.50 x D

   If the rutting is suspected to be caused by the base or subgrade, coring (or cross sectional sampling) will be conducted by CDOT to determine the cause of the rutting.

2. *Pot Holes.* Pot holes are bowl shaped depressions of various sizes in the pavement surface caused by loss of pavement mix.

   Remedial action for potholes > 1.0 inches deep and > 1 ft² in area: affected area shall be repaired by removal and replacement to 2 feet beyond the apparent distress.

3. *Longitudinal Joint Separation.* Longitudinal Joint Separation is loss of the pavement surface or depressions near a longitudinal joint.

   Remedial Action for longitudinal joint separation > 0.5 inches deep: affected area shall be removed and replaced 6 inches beyond the distress laterally and to 2 feet beyond the distress longitudinally.

4. *Raveling and Weathering.* Raveling and weathering are the wearing away of the pavement surface caused by the dislodging of aggregate particles (raveling) and the loss of asphalt binder (weathering).

   Remedial action for raveling and weathering > 0.25 inches deep and > 1 ft² in area: affected area shall be removed and replaced to 2 feet beyond the apparent distress.

5. *Bleeding*. Bleeding is a film of bituminous material on the pavement surface which creates a shiny, glass-like, reflective surface.

Severity	Quantity	Remedial Action Required
Low	Coloring of surface visible	Observe more frequently
Moderate to High	Asphalt free on surface	Remove and replace full width of lane or shoulder to 2 feet longitudinally beyond affected area.

6. *Delamination of Pavement Layers.* Delamination of pavement is the separation of one layer from the layer below it.

   Remedial action for delamination: affected area shall be removed and replaced to 1 foot beyond the apparent distress.

7. *Transverse Cracking*. Transverse cracks are cracks relatively perpendicular to the pavement centerline. The highest severity level present for at least 10% of the total length of the crack shall be assigned. Random cracks with transverse cracks are cracks that occur randomly and are within 2 feet of the transverse crack. Spalling with transverse cracks is the cracking, breaking or chipping of the pavement surface within 2 feet of the transverse crack.

Severity	Quantity	Action Required
Low	< 0.25 inches wide	Seal cracks with hot poured joint and crack sealant materials that meet the requirements of ASTM D 3405.
Moderate	< 0.75 inches wide < 0.25 inches wide with spalling or random cracking	
High	> 0.75 inches wide	Remove and replace full width of lane or shoulder to 1 foot longitudinally beyond the apparent distress.
	< 0.75 inches wide with spalling and random cracking	

(e) **Elective or Preventive Action**. The Contractor or Surety shall submit a written proposal to the Engineer if it proposes to perform elective or preventive work. The Engineer will forward the proposal to the PET for a final decision. Elective or Preventive action shall be a Contractor or Surety option subject to the approval of the Engineer. Elective or Preventive work shall be done during times set forth in the Contract for original contract work. Lane rental fees will be assessed.

(f) **Emergency Work.** The Engineer may request immediate action of the Contractor and Surety for the safety of the traveling public. The Contractor or Surety shall have the first option to perform the emergency work. If the Contractor or Surety cannot perform the emergency work within 24 hours, the Engineer may have the emergency work done by other forces and seek reimbursement from the Contractor or Surety accordingly. Emergency work performed by other forces shall not alter the requirements, responsibilities, or obligations of the warranty.

(g) **Traffic Control**. Construction Traffic control for warranty work shall be performed in accordance with Section 630 at the Contractor's expense.

(h) **Process Control Testing:** The Contractor shall perform process control testing in accordance with the Revision of Section 106, Quality Control for Warranted Hot Bituminous Pavement.

-8-

REVISION OF SECTION 403
WARRANTED HOT BITUMINOUS PAVEMENT

METHOD OF MEASUREMENT

Warranted bituminous pavement will be measured for payment by the ton of mixture based on the quantity of mixture placed, completed and accepted. The Contractor shall present asphalt scale tickets to the Engineer on a daily basis for the quantities placed under this special provision.

BASIS OF PAYMENT

Warranted bituminous pavement, measured as provided above, will be paid for at the contract unit price per ton of mixture, which price will be full compensation for furnishing, preparing, hauling, mixing and placing all materials, including asphaltic materials, for compacting mixtures, for the warranty and warranty bonds, for performing warranty work, for the materials mix design, for the Quality Control Plan, for testing, record keeping, sampling, and for all labor, tools, and equipment during construction and during the warranty period, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	**Pay Unit**
Hot Bituminous Pavement (5 Year Warranty)	Ton

The pay quantity shall be the actual quantity of warranted bituminous pavement placed, not to exceed 105% of plan quantity.

Water used in the mixing plant to bring the lime-aggregate mixture to approved moisture content will not be measured and paid for separately but shall be included in the work.

Facilities for testing hot bituminous plant mix at the site of the commercial plant will not be paid for separately, but shall be included in the work.