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COST-BENEFIT EVALUATION COMMITTEE

MATERIALS AND WORKMANSHIP WARRANTIES FOR HOT BITUMINOUS PAVEMENT



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16. Abstract The objective of this evaluation was to document a cost-benefit evaluation of the 3-year warranty specification and projects for hot bituminous pavements (HBP). There were 6 warranty projects evaluated that included 3 projects whose warranty terms had expired. When reviewing the conclusions it is important to understand there were a limited number of projects. Each warranty project was compared to a comparable non-warranted project. The cost comparisons included costs for the initial HBP, maintenance, pavement evaluation team, weigh-in-motion station, and construction engineering. An analysis was also conducted on the competition, performance, and use of experimental features. Based on these projects, there was no appreciable difference in competition or performance of the warranty projects compared to the control projects. The differential of initial cost of the warranty projects compared to the non-warranted projects was determined to be negligible. The largest warranty cost identified was \$80,000 for the weigh-in-motion station installation and maintenance. This cost was approximately 3% of the overall project cost. Several lessons were learned on these projects, and recommendations were made to improve the current specification. It appears the quality was acceptable, but it may be more of a result of the QC / QA specification that was put in place approximately 10 years ago rather than the warranty specification. Contractors that had responded to the QC / QA specification were those that were awarded these warranty projects. Implementation At this time there was no strong cost-benefit evidence to suggest that either continuation or stoppage of the 3-year warranty program would be beneficial to CDOT. The full implementation plan needs to be followed and carried out. A re-evaluation should occur at that time.			
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Executive Summary

Philosophy. Under a warranty specification the contractor is allowed to use innovative practices to provide the necessary quality during construction. By removing some of the prescriptive specifications, the contractor is 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.

Under a materials and workmanship warranty, the contractor may still not be responsible for many pavement defects, including the kinds of design defects that were a primary cause of the premature failures on several Colorado Department of Transportation (CDOT) projects in the late 1980's and early 1990's. 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.

Objective. The objective of this report was to document a cost-benefit evaluation of the 3-year warranty specification and projects for asphalt pavements. This evaluation covered a total of 6 warranty projects that were awarded of which 5 had been constructed and 1 was under construction. Three of the projects had reached the end of their 3-year warranty term.

Benefit - Cost. There was limited data available from the awarded 6 warranty projects that included 3 projects whose warranty terms had expired. There was no appreciable difference in competition or performance of the warranty projects when compared to the control projects. The exception was the longitudinal cracking on the C-470 project. In order to ensure improved performance and quality on future projects, it is imperative that the lessons learned from these experimental projects be implemented. These lessons include Recommendation #1 (accountability for the shift in responsibility) and Recommendation #2 (adding segregation distress thresholds to the specification) as stated in the Summary and Recommendations Chapter.

Although there was an appreciable cost differential, \$85,400 or approximately 3% of the overall project cost, \$80,000 of that was for the weigh-in-motion station. Recommendation #3 (evaluate use of Pavement Management System data to trigger evaluations) and Recommendation #4 (reevaluation of the weigh-in-motion requirement) could address these cost concerns.

There was a shift in risk and responsibility as a result of the warranty projects, but at this time there was no tangible benefit identified. At this time there was no strong cost-benefit evidence to suggest that either continuation or stoppage of the 3-year warranty program would be beneficial to CDOT.

Quality. It appears the quality was acceptable, but it may be more of a result of the QC/QA specification that was put in place approximately 10 years ago rather than the warranty specification. Contractors that had responded to the QC/QA specification were those that were awarded these warranty projects.

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One of the warranty projects had no tester and reduced inspection. This resulted in a reduction to the Construction Engineering Costs for that particular project. Due to the nature of the Construction Engineering Pool, it was not possible to gather construction-engineering costs for the warranty and control projects in order to make a comparison.	
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CHAPTER 1: Introduction

Warranty Philosophy:

The philosophy of a warranty is the same, whether applied to any manufactured product or to pavements. The manufacturer is held liable for the performance of their product within the bounds of what the product was designed for and for the parameters for which the manufacturer has control. What does that mean for pavements?

Manufacturers of hot mix asphalt design pavements for specified levels of traffic. The properties of the mixture and the components are within control of the manufacturer (the contractor). The philosophy of offering a warranty means that any deficiencies related to properties of the hot mix asphalt or components thereof are the liability of the manufacturer.

What happens when a pavement deteriorates and breaks up, especially if the pavement failure occurs relatively soon after it was constructed? Is it the owner's responsibility or the contractor's? The answer depends on the latitude the contractor had during construction. A warranty may not be a cure all for all defects.

Potential Benefits and Costs.

Currently, the way projects are typically bid provides contractors with little opportunity for innovation. A contractor has little opportunity to deviate from standard specifications and, providing that the specifications are met, should not be liable for shortcomings in performance. The current specifications are designed as a prescriptive specification to yield a pavement that performs in a way which ensures the lowest cost 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 necessary quality during construction (1). By removing some of the prescriptive specifications, 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. In addition, there is a growing realization that the adversarial or confrontational attitude that exists between the agency and the contractor needs to be modified and a more cooperative attitude fostered between the two groups. 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. (2)

Warranties are likely to have additional costs than 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 more properly be viewed 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. On the other hand, there may also be some savings to contractors. Removing prescriptive specifications may allow contractors to improve efficiency (1).

Types of Warranties.

There are a variety of types of pavement warranties. The terms of the warranty commonly range from 3 years to 10 years. The purpose of the warranty depends on who takes on a set of specific responsibilities and the associated risk with each of those responsibilities. Whoever has a specific responsibility will take the risk in case of premature distress due to that specific responsibility. 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 for all of these items. Depending on the type of warranty, CDOT should likely remain responsible for a majority of these items. Other examples of items are materials specifications and workmanship specifications. It is very important that a conscientious risk allocation process take place when developing any type of warranty specification. A successful risk allocation process will clearly define who is responsible for what.

Following are four definitions of different types of warranties.

Prepaid Maintenance Warranties. With this type of warranty the owner is responsible for specifying the pavement design, the materials properties and the prescriptive workmanship process. The contractor is responsible for following and meeting all of these specifications. In addition, the contractor must warranty the resulting pavement for a certain period of time. Essentially, the contractor is responsible for developing an estimate to maintain the pavement as built by the owner's requirements. CDOT does not have a warranty specification like this at this time. However, at least one state has recently implemented this concept.

Workmanship Warranties. The contractor is responsible for correcting defects in work elements within the contractor's control during the warranty period. This includes distresses resulting from poor workmanship. The owner is responsible for the pavement structural design. The contractor assumes no responsibility for structural design or those distresses that result from the design. Responsibility is shifted from the owner to the contractor for workmanship. The purpose would be to address some of the historic issues that result in shorter pavement lives; for example, the potholes that result from segregation in Hot Bituminous Pavement (HBP) or the pop outs that result from clay balls in Portland Cement Concrete Pavement (PCCP). This is the type of short-term (5-year) warranty that CDOT has developed for PCCP workmanship.

Materials and Workmanship Warranties. The contractor is responsible for correcting defects in work elements within the contractor's control during the warranty period. This includes 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 (3). 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 (3 to 5 year) warranty that CDOT has developed for HBP materials and workmanship.

Performance Warranties. The contractor assumes full responsibility for pavement performance during the warranty period. In effect, the contractor guarantees that the pavement will perform at a desired quality level. The contractor assumes responsibility for some or all of the pavement design decisions (3). This is the type of long-term (10 years or greater) warranty that CDOT is analyzing the feasibility of HBP and PCCP performance. At this point in time, a 10-year term is the longest that is potentially feasible. With only a 10-year warranty on a 30-year design, this performance warranty might be better described as a limited performance warranty because CDOT will need to retain control over some of the design decisions. The use of a warranty period that is less than the entire pavement design might still provide a reasonable assurance that the pavement would hold up for the entire design life. However, it is not clear what the most cost-effective warranty period should be. The ideal warranty period should be long enough to provide assurance of pavement performance, but not so long as to unnecessarily inflate contract prices (3).

Warranty Limitations.

Under a materials and workmanship warranty, the contractor may still not be responsible for many pavement defects, including the kinds of design defects that were a primary cause of the premature failures on several CDOT projects in the late 1980's and early 1990's.

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 (3).

Roles and Responsibilities.

Regardless of the type of warranty specification in place, there are responsibilities for the contractor and owner. These responsibilities need to be clearly defined and followed.

The contractor has the responsibility and risk to warrant the work after it is completed. Therefore, the contractor has the right (and the risk) to define how the work is to be accomplished and to warrant that work after it is completed.

The owner has the responsibility to inspect and record all materials and processes that might cause disputes about the invocation of the warranty at a later date. The continuous checking or inspection of all the paving work must be done according to the standards defined in the contract (2).

Summary.

The purpose of this paper is to examine several short-term materials and workmanship warranty projects with HBP and determine if the warranty philosophy translates into reality. Are the benefits to the highway owner sufficient to justify the increased cost?

References:

- (1) Hardaway, Curt (May, 2001), "New Contract Procedures may Provide Some Incentives," Better Roads, pages 56-6.

- (2) Hueppi, Peter (1992), "Cooperative Attitudes Between Contractors and Governmental Agencies in Europe," Journal of the Association of Asphalt Paving Technologists, pages 624-636.
- (3) Hamilton, William E. (March, 2001), "Transportation: Road Construction Warranties," Michigan House Fiscal Agency Legislative Briefing, 8 pages.

Background:

On May 21, 1997, Senate Bill 97-128 was approved. The Senate Bill established a pilot program for the warranty of hot bituminous pavement (HBP) projects. The legislation required three projects located along the Front Range to be bid in 1997 or 1998. The Colorado Department of Transportation (CDOT) complied with the Senate Bill. A copy of the Senate Bill is in Appendix A.

CDOT was interested in further examining the use of HBP warranties. The next two warranty projects were advertised but were unsuccessfully bid. One project had a 5-year warranty and there was only one bidder, and this bid was significantly over the engineer's estimate. The other project was a 10-year warranty but the three bidders were significantly over the engineer's estimate. CDOT then decided to develop a strategic direction for its vision with warranties. The strategic direction paper was signed on November 4, 1999 and a copy of the "Pavement Warranty Provisions: CDOT's Future Direction" is in Appendix B. The strategic direction calls for further experimentation with the short-term materials and workmanship HBP warranties, the creation of short-term materials and workmanship PCCP warranty, and the examination of the feasibility of long-term performance warranties.

In order to obtain the best possible chance of success with the short-term materials and workmanship HBP warranty, a joint CDOT and industry task force was created. In late 1999 and early 2000 this task force produced three products. This task force reviewed and updated the specification based upon the results and lessons learned on the first three projects. This group also developed Project Selection Guidelines and developed an Implementation and Evaluation Plan that are in Appendix C. A 3-year warranty term was recommended for projects that were designed for 10 years and a 5-year warranty term was recommended for projects that were designed for 20 years.

Further coordination was required with the Federal Highway Administration (FHWA). The letter obtaining the FHWA approval is dated November 8, 1999, and it is in Appendix D.

The specification used on the first three projects constructed in 1998 is in Appendix E and the specification used on the 2000 and 2001 projects is in Appendix F.

Objective:

The objective of this report was to document a cost-benefit evaluation of the HBP warranty specification and projects. As required by the Senate Bill a committee selected by the Transportation Commission performed this evaluation. Further, the purpose of this paper was to report the lessons learned from these experimental projects and make recommendations for the future direction of the short-term materials and workmanship HBP warranties by CDOT.

Scope:

CDOT elected to pilot more than the three projects required by the Senate Bill. Therefore, it was decided to include all of the short-term materials and workmanship HBP warranty projects in this evaluation. This paper covered a total of 6 warranty projects that were awarded of which 5 had been constructed and 1 was under construction. Three of the projects had reached the end of their three-year warranty term. Each year this report will be updated as cost and performance data become available from the additional warranty projects that CDOT constructs.

Team:

As required by the Senate Bill, a committee consisting of 2 representatives from CDOT, 2 individuals from the asphalt paving industry, and one independent consultant was formed. As required by the legislation, the Transportation Commission on Thursday, March 15, 2001 approved this group. For information purposes, this was the third group that the Transportation Commission approved due to high levels of turnover within CDOT and industry.

The 2 CDOT representatives were:

- Tim Aschenbrener, Materials and Geotechnical Branch Manager
- Gary Self, Contracts and Market Analysis Branch Manager

The 2 industry representatives were:

- Kevin Anderson, Aggregate Industries Operations Manager
- Ken Coulson, Coulson Excavating Company Vice-President

The independent consultant was:

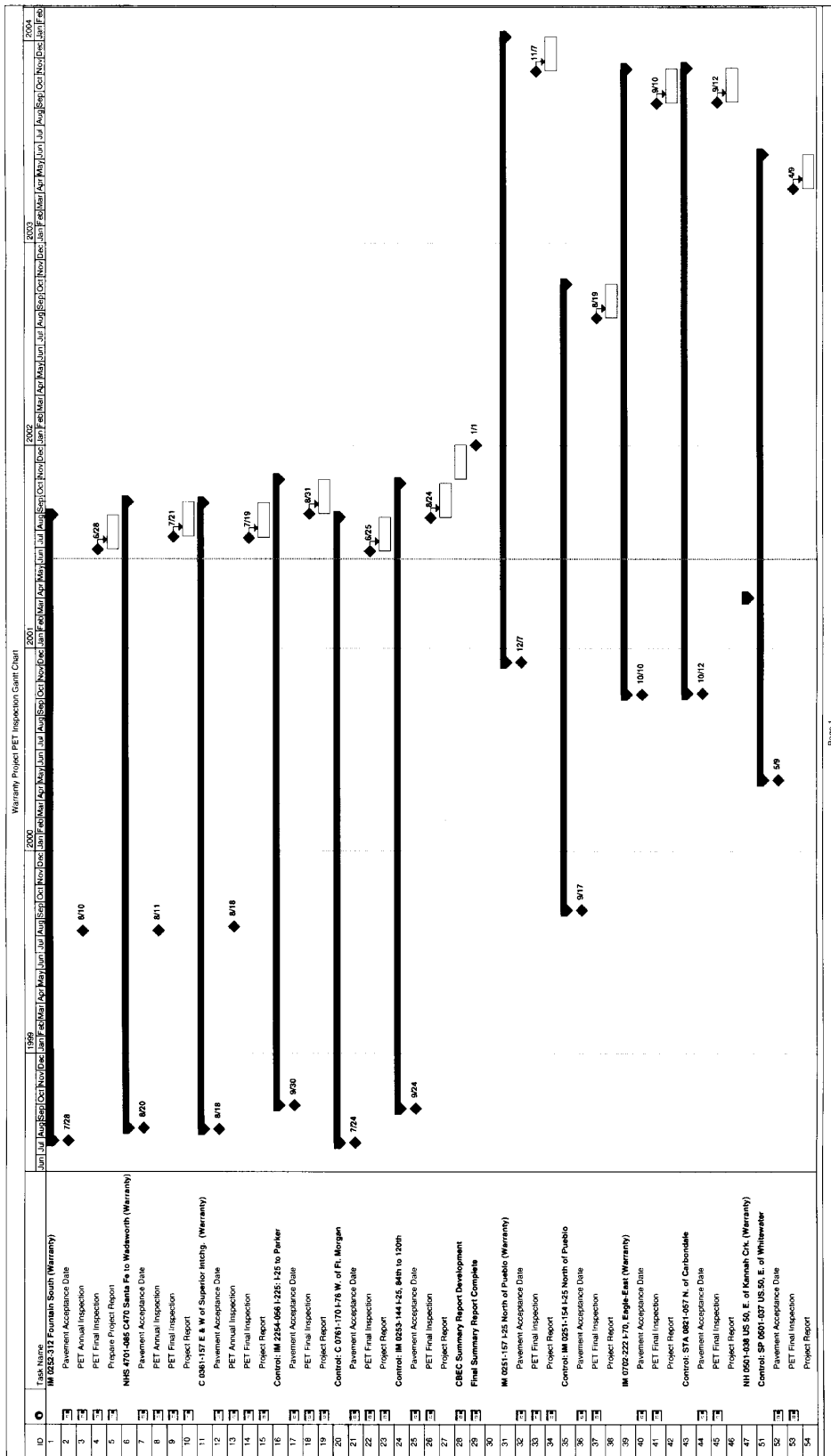
- Jim Fife, Western Colorado Testing Inc., President

Roberto DeDios was from CDOT's Materials and Geotechnical Branch and works in the Pavement Management and Design Program. Roberto co-authored this report, researched the warranty and non-warranty projects, and compiled the data within the report.

Coordination and Schedule:

To ensure a successful effort, coordination was needed with the Pavement Evaluation Team (PET). The PET had data on performance and was gathering information on maintenance required by the contractor. This was valuable information that was needed for the cost benefit evaluation. Several meetings were held between the two groups to ensure coordination.

The schedule developed is shown in Table 1.



CHAPTER 2: Information Gathering

Projects to Date:

A list of all the short-term, materials and workmanship HBP projects included in this report is shown below.

- Region 2: IM 0252-312, I-25 South of Fountain (constructed summer of 1998)
- Region 6: NHS 4701-085, C-470 from Santa Fe to Wadsworth Blvd. (constructed summer of 1998)
- Region 4: C 0361-157, US-36, E&W of Superior Interchange (constructed summer of 1998)
- Region 2: IM 0251-157, I-25, North of Pueblo (constructed summer of 2000)
- Region 3: IM 0702-222, I-70, Eagle to Avon (constructed summer of 2000)
- Region 3: NH 0501-038, US-50, East of Kannah Creek (constructed summer of 2001)
- Region 2: SH-67 (constructed summer of 2001)

Selection of Control Projects:

In order to perform the cost-benefit analysis, control projects were selected. The control projects used the traditional CDOT specifications (non-warranty) and were comparable to the warranty projects in terms of year of construction, overlay thickness, rehabilitation strategy, traffic, and original pavement condition. It was not possible to obtain perfect matches between the warranty and control projects, but as reasonable a match as possible was obtained.

Information in Metric projects was converted into English units for ease of comparison. All units in this report are in English.

Discussions with CDOT's and Contractor's Representatives:

In order to gain an understanding of the experiences on the project, information was gathered. CDOT's representatives, the Resident Engineer and Project Engineer, were contacted. The Contractor's representative, the Project Superintendent, was also contacted. These contacts were asked about the areas of the project relating to the warranty specification that went well and those areas that needed improvement. The information is documented in Chapter 9.

CHAPTER 3: I-25 South of Fountain

Experimental and Control Project Information:

The experimental project (warranty) was on I-25 and extended southerly from Fountain for 3.8 miles from Milepost 124.05 to Milepost 127.87. It was in El Paso County. The Colorado Project Number was IM 0252-312 (Subaccount No. 12116). This project was in Metric units.

The control project was on I-25 north of Pueblo and extended northerly for approximately 6.4 miles from Steel Hollow, Milepost 109 to Young Hollow, Milepost 115.4. It was in Pueblo County. The Colorado Project Number was IM 0251-154 (Subaccount No. 12528). This project was in English units. This project was also used as the control project for the experimental project on I-25, north of Pueblo (Colorado Project Number IM 0251-157, Subaccount No. 13048) in Chapter 6 of this report.

A comparison of the information from the experimental (warranty) and control (non-warranty) projects is summarized below.

	Experimental Project	Control Project
Overlay Thickness	4 inches	4 inches
Rehabilitation Strategy	1"(NB lane) & 2-1/2" (WB lane) 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
10-year Design ESALs	5,162,000	5,372,000
Existing Pavement Structure	6.5" HBP & 12" Aggregate Base Course	9.25"HBP & 12"ABC

The existing pavement structure was measured prior to the construction project. Both projects had hot bituminous pavement (HBP) and aggregate base course (ABC). A summary of the existing pavement structure of all projects is shown in Appendix G.

Cost Data:

Contract Costs.

The successful contractor's bid on the warranty project was 88% of the engineer's estimate. The four bids ranged from 88% to 95% of the engineer's estimate. The successful contractor's cost per ton of warranted hot bituminous pavement (HBP) was \$35.38, which was 87% of the engineer's estimate at \$40.82.

For the control project, the successful contractor's bid was 93% of the engineer's estimate. The six bids ranged from 93% to 130% of the engineer's estimate. The successful contractor's cost per ton of HBP was \$32, which was 91% of the engineer's estimate at \$35.

The tonnage information for the control project in the following table represents only the quantity of HBP used to construct the specified overlay thickness.

	Experimental Project	Control Project
Tonnage	44,667	53,422
Project Low Bid	\$2,759,534.02	\$4,634,123.50
Engineer's Estimate	\$3,134,297.83	\$4,992,311.54
Low Bid, \$/ton	\$35.38	\$32
Engineer's Estimate, \$/ton	\$40.82	\$35
Type of Binder	AC-20/PG 70-34	AC-20R
Warranty Line Item, L.S.	NA	NA
No. of Bidders	4	6

In order to develop the engineer's estimate for the warranty project, 10% was added to the estimated cost per ton of warranted HBP. The 10% was developed based on engineering judgement and was intended to cover 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.

Although there is an obvious difference between the unit cost of the engineer's estimate and the contractor's low bid in the experimental project, it can be assumed with high level of confidence that the engineer's estimate of warranty cost of 10% is reasonable. This was because variations of this magnitude between the low bid and the engineer's estimate for this bid item in non-warranty projects were very common. A detailed cost analysis of all the projects is provided in Chapter 10.

Line Item Profiles for Evaluating Overall Project Cost.

Based on the line item profile output, 14 bid items were found to have deviations greater than the default value of +/-1 percent. Mobilization was the only lump sum item in this category where additional costs could be conveniently loaded. The low bidder had a mobilization cost that was second to the lowest. It exceeded the engineer's estimate by \$22,500, which was above the total project cost by 0.70%. One bidder's mobilization cost was below the engineer's estimate. All the other 3 bidders had mobilization costs above the engineer's estimate. Overall, it appeared that there was no unbalancing of the bid item costs by the low bidder in this contract.

Maintenance Costs.

The Maintenance Management System (MMS) was used to track all of CDOT's maintenance activities on a particular segment of highway. Those included a variety of activities, but of particular interest for this report were those related to the roadway surface (minor patching, machine patching, crack sealing, chip sealing, fog coating, blading shoulder, and base stabilization). The costs of CDOT roadway surface maintenance activities are summarized below for the warranty and control project as gathered in MMS. The Pavement Evaluation Team also identified the costs of the contractor for maintenance performed under the warranty.

	Warranty Project (\$)	Control Project (\$)
CDOT – FY 1999	0	0
Contractor – FY 1999	0	0
CDOT – FY 2000	0	2,776
Contractor – FY 2000	0	NA
CDOT – FY 2001	0	12,309
Contractor – FY 2001	will be some CDOT would have done none	NA
Totals	0	\$15,085

Competition Data:

The bid competition in the warranty and control projects was very similar. The bid competition in the warranty project with four bidders was slightly less than that of the control project with six bidders.

Performance Data:

The performance of the experimental and control projects was measured by two methods: the Pavement Evaluation Team (PET) and the pavement management automated data collection van. Measuring pavement distress is very subjective and it is very difficult to get repeatable results. Both of these methods of measurement have advantages and weaknesses. By using both sets of data, it was hoped to minimize the chance for errors. Both sets of data are shown below.

Pavement Evaluation Team.

The PET documented the observed distresses that were warranted on the project. They are summarized below.

- Permanent Deformation:
 - August 10, 1999 0 mm to 2 mm (avg. 0.23 mm)
 - September 27, 2000 0 mm to 2 mm (avg. 0.15 mm)
 - May 15, 2001 0 mm to 3 mm (avg. 1.1 mm)
 - All measurements were found to be below the threshold levels of the parameters of the specification. The actual ESALs were below the design threshold ESALs.
- Pot Holes:
 - August 10, 1999 not observed
 - September 27, 2000 not observed
 - May 15, 2001 not observed
 - All measurements were found to be below the threshold levels of the parameters of the specification.
- Longitudinal Joint Separation:
 - August 18, 1999 one short length observed

September 27, 2000 quite extensive

May 15, 2001 quite extensive, remedial action required

After the third evaluation the threshold levels of the parameters of the specification were exceeded. The longitudinal joint for the entire project shall receive remedial action. The PET sent a letter to the Project Engineer on May 31, 2001.

- Raveling and Weathering:

August 18, 1999 not observed

September 27, 2000 not observed

May 15, 2001 not observed

All measurements were found to be below the threshold levels of the parameters of the specification.

- Bleeding

August 18, 1999 not observed

September 27, 2000 not observed

May 15, 2001 not observed

All measurements were found to be below the threshold levels of the parameters of the specification.

- Delamination of Pavement Layers

August 18, 1999 not observed

September 27, 2000 not observed

May 15 2001 not observed

All measurements were found to be below the threshold levels of the parameters of the specification.

- Transverse Cracking

Not included because the contractor used the PG 70-34 binder.

The control project was constructed 1-year later than the experimental warranty project. The results from the PET review of the control project will be available in the fall of 2002.

Pavement Management System.

CDOT subcontracts all data collection. The data collection vendor drives an automated data collection van over all of the required highway miles and reports the data on 1/10-mile increments. For rut data, the van is equipped with a five-sensor rut bar that measures rut to the hundredth of an inch. Ride data is collected with an inertia profiler consisting of laser sensors, accelerometer, and distance transducer. All cracking data is reduced from video footage. The van is equipped with five video cameras, one windshield view and four pavement views (one over each wheel). All video data is recorded on Super VHS video cassettes and sent to the vendor's data reduction office where the cassettes are viewed in slow motion and rated. This raw data is what the vendor delivers to CDOT.

The database that CDOT receives reports the pavement condition on 1/10-mile intervals. Ride is reported as average inches/mile and rut is reported as average hundredths of an inch. Block

cracking and fatigue cracking are reported as total square feet, longitudinal cracking is reported as total linear feet, and transverse cracking is reported as a count. A crack index is calculated for each of six different types of cracks (fatigue cracking, block cracking, transverse cracking, longitudinal cracking, alligator cracking, and load associated longitudinal cracking). The lowest crack index, the one showing the greatest distress, was most commonly the load associated longitudinal (LAL) cracking and it is shown on the following tables. All cracking has three categories of reporting, low, moderate, and high severity distress.

The raw data for all distresses are manipulated through equations and transformed into an Index Value. The equations combine the raw data for a given distress, the maximum possible amount of distress, and the minimum amount of distress, then convert the raw data to a rating of 1 to 100. This is the Index Value. A rating of 100 indicates a perfect pavement and a rating of 50 or less indicates pavement failure.

The Index Values inherently contain slight variances; several factors contribute to this. The subjective nature of pavement rating can cause slight fluctuations in the Index Value. A change in data collection vendors or instruments could affect the Index Value. Every year an Index Equation Task Force is convened to review the accuracy and effectiveness of the equations. If the task force tweaks a variable or alters a parameter, the repercussions of the modifications could alter the Index Value. The time of year in which the project is completed also affects whether the condition data will be available directly after construction. For example, if the project is completed in the Spring, the data collection van will pass over the project soon after it has been completed and data will be available for the immediate condition after construction. However, if the project is completed in the summer, data will not be available until the next annual pass from the data collection van.

Experimental Project

	Ride Index	Rut Index	LAL Crack Index
Condition Prior To Construction	79	79	61
Condition After Construction	99	100	100
Condition After 1 Year (1999)	95	100	100
Condition After 2 Years (2000)	88	100	97
Condition After 3 Years (2001)	92	100	97

Control Project

	Ride Index	Rut Index	LAL Crack Index
Condition Prior To Construction	79	91	82
Condition After Construction	99	100	99
Condition After 1 Year (2000)	88	100	99
Condition After 2 Years (2001)	90	100	99
Condition After 3 Years (2002)			

Project Specific Features:

The contractor constructed 8 replicate experimental test sections and one replicate control section to gain a better understanding of the performance of various types of rehabilitation techniques. These techniques included a variety of crack filling and fabric treatments. These treatments were intended to mitigate the reflection of existing distresses through the newly placed overlay.

CHAPTER 4: C-470, Santa Fe Drive to Wadsworth Blvd.

Experimental and Control Projects Information:

The experimental project (warranty) was on C-470 and extended west of Santa Fe Drive to Wadsworth Blvd. for approximately 3.1 miles from Milepost 13.86 to Milepost 16.92 . It was in Arapahoe, Douglas, and Jefferson Counties. The Colorado Project No. was NHS 4701-085 (Subaccount No. 11595).

There were two control projects for this warranty project. The first control project was on I-25 and extended north beginning at 84th Avenue to 120th Avenue for approximately 4.4 miles from Milepost 218.70 to Milepost 223.06. It was in Adams County. The Colorado Project No. was IM 0253-144 (Subaccount No. 11593R).

The second control project was on I-225 and extended northeast beginning at I-25 Interchange to Parker Road for approximately 4 miles from Milepost 0.0 to Milepost 3.95. This project had 4-inch and 2-inch hot bituminous pavement (HBP) sections. The 2-inch segment extended from Milepost 3.14 to Milepost 3.95. This project was in Arapahoe and Denver Counties. The Colorado Project No. was IM 2254-056 (Subaccount No. 11594).

All of the above three projects were built with night paving operations. All three projects were originally in Metric units. A comparison of the information from the experimental (warranty) and the control (non-warranty) projects is summarized below.

	Experimental Project	1 st Control Project	2 nd Control Project
Overlay Thickness	2 inches	2 inches	2 inches
Rehabilitation Strategy	½-inch milling	2-inch milling	2-inch milling
Award Date	March 18, 1998	May 21, 1998	April 1, 1998
Begin Construction Date	May 4, 1998	June 10, 1998	May 6, 1998
Project Acceptance Date	August 20, 1998	September 24, 1998	September 30, 1999
Facility Type	4-lane Interstate	4-lane Interstate	4-lane Interstate
10-year Design ESALs	3,688,000	9,231,000	7,424,000
Existing Pavement Structure	6.5”HBP & 17”ABC	5” to 9” HBP	11” HBP

The existing pavement structure was measured prior to the construction project. The experimental project had hot bituminous pavement (HBP) and aggregate base course (ABC). The first control project had a varying thickness of HBP with undetermined type and depth of base course materials. The second control project was full depth HBP. A summary of the existing pavement structure of all projects is shown in Appendix G.

Cost Data:

Contract Costs.

The successful contractor's bid on the warranty project was 98% of the engineer's estimate. The two bids ranged from 98% to 115% of the engineer's estimate. The successful contractor's cost per ton of warranted HBP was \$37.19, which was 98% of the engineer's estimate at \$38.10.

For the first control project, the successful contractor's bid was 107% of the engineer's estimate. The two bids ranged from 107% to 110% of the engineer's estimate. The successful contractor's cost per ton of HBP was \$47.63, which was 105% of the engineer's estimate at \$45.36.

For the second control project, the successful contractor's bid was 102% of the engineer's estimate. The three bids ranged from 102% to 117% of the engineer's estimate. The successful contractor's cost per ton of HBP was \$42.64, which was 109% of the engineer's estimate at \$39.

The tonnage information for the 1st control project in the following table represents only the quantities of HBP used to construct the specified overlay thickness. The tonnage information for the 2nd control project includes both the 2-inch and 4-inch thick overlays.

	Experimental Project	1 st Control Project	2 nd Control Project
Tonnage	19,153	26,459	44,681
Project Low Bid	\$1,576,028.40	\$3,472,977.79	\$3,746,136.20
Engineer's Estimate	\$1,615,756.50	\$3,247,160.50	\$3,688,330.90
Low Bid, \$/ton	\$37.19	\$47.63	\$42.64
Engineer's Estimate, \$/metric ton	\$38.10	\$45.36	\$39.00
Type of Binder	PG 76-28	PG 76-28	PG 76-28
Warranty Line Item	NA	NA	NA
No. of Bidders	2	2	3

In order to develop the engineer's estimate for the warranty project, 10% was added to the estimated cost per ton of warranted HBP. The 10% was developed based on engineering judgement and was intended to cover 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.

Based on the closeness of the cost per ton of the engineer's estimate to the successful contractor's low bid in the experimental project, it appeared that the engineer's estimate of the warranty cost of 10% was very reasonable. A detailed cost analysis of all the projects is provided in Chapter 10.

Line Item Profiles for Evaluating Overall Project Cost.

There were 13 bid items that were found to have deviations greater than the default value of +/-1 percent. Construction surveying, mobilization, and WIM station (Type 2) costs were the only three lump sum items in this group. The low bid for construction surveying was only \$5,000 and obviously was not carrying extra cost. The mobilization cost by the low bid was \$62,000 more than

the engineer's estimate. In contrast, the WIM station (Type 2) cost was \$65,000 less than the engineer's estimate. The low bid unit cost per metric ton of HBP (Asphalt)(3-Year Warranty) was only \$1.00 less than the engineer's estimate and the quantity was relatively small at 19,153 tons. This would not support the suggestion that the price was reduced to load up the other items. There was no significant unbalancing of the bid item costs in this contract.

Maintenance Costs.

The Maintenance Management System (MMS) was used to track all of CDOT's maintenance activities on a particular segment of highway. Those included a variety of activities, but of particular interest for this report were those related to the roadway surface (minor patching, machine patching, crack sealing, chip sealing, fog coating, blading shoulder, and base stabilization). The costs of CDOT roadway surface maintenance activities are summarized below for the warranty and control project as gathered in MMS. The Pavement Evaluation Team also identified the costs of the contractor for maintenance performed under the warranty.

	Warranty Project (\$)	Control Project #1 (\$)	Control Project #2 (\$)
CDOT – FY 1999	0	0	0
Contractor – FY 1999	0	0	0
CDOT – FY 2000	0	1,175	348
Contractor – FY 2000	0	NA	NA
CDOT – FY 2001	0	1,012	565
Contractor – FY 2001	will be some - CDOT would have done none	NA	NA
Totals	\$ 0	\$ 2,187	\$ 913

Competition Data:

The bid competitions in the warranty and two control projects were very similar. The warranty project had 2 bidders and the first control project also had 2 bidders. The second control project had 3 bidders.

Performance Data:

The performance of the experimental and control projects was measured by two methods: the Pavement Evaluation Team (PET) and the pavement management automated data collection van. Measuring pavement distress is very subjective and it is very difficult to get repeatable results. Both of these methods of measurement have advantages and weaknesses. By using both sets of data it was hoped to minimize the chance for errors. Both sets of data are shown below.

Pavement Evaluation Team.

The PET documented the observed distresses that were warranted on the project. They are summarized below.

- Permanent Deformation:

August 11, 1999 0 mm to 4 mm (avg. 1.83 mm)

October 16, 2000 1 mm to 6 mm (avg. 2.83 mm)

June 22, 2001 1 mm to 5 mm (avg. 3.48 mm)

All measurements were found to be below the threshold levels of the parameters of the specification. The actual ESALs were below the design threshold ESALs.

- Pot Holes:

August 11, 1999 not observed

October 16, 2000 not observed

June 22, 2001 not observed

All measurements were found to be below the threshold levels of the parameters of the specification.

- Longitudinal Joint Separation:

August 11, 1999 some hairline cracking observed

October 16, 2000 minor and intermittently observed

June 22, 2001 several segments exceeded the threshold

Warranty work will be required at approximately 10 locations throughout the project.

- Raveling and Weathering:

August 11, 1999 several small area observed

October 16, 2000 several small areas observed

June 22, 2001 not observed

All measurements were found to be below the threshold levels of the parameters of the specification.

- Bleeding

August 11, 1999 not observed

October 16, 2000 not observed

June 22, 2001 not observed

All measurements were found to be below the threshold levels of the parameters of the specification.

- Delamination of Pavement Layers

August 11, 1999 not observed

October 16, 2000 not observed

June 22, 2001 not observed

All measurements were found to be below the threshold levels of the parameters of the specification.

- Transverse Cracking

Not included because the contractor used the PG 76-28 binder.

The PET documented the observed distresses on the control project. They are summarized below. Industry elected not to participate in the PET review of this control project. The results are based upon the CDOT and consultant evaluation.

- **Permanent Deformation:**
June 30, 2001 1 mm to 5 mm (avg. 2.40 mm)
All measurements were found to be below the threshold levels of the parameters of the specification. Based on ESAL projections, the actual ESALs were below the design threshold ESALs.
- **Pot Holes:**
June 30, 2001 not observed
All measurements were found to be below the threshold levels of the parameters of the specification.
- **Longitudinal Joint Separation:**
June 30, 2001 two segments exceeded the threshold
Warranty work would have been required at approximately 2 locations throughout the project.
- **Raveling and Weathering:**
June 30, 2001 not observed
All measurements were found to be below the threshold levels of the parameters of the specification.
- **Bleeding**
June 30, 2001 not observed
All measurements were found to be below the threshold levels of the parameters of the specification.
- **Delamination of Pavement Layers**
June 30, 2001 not observed
All measurements were found to be below the threshold levels of the parameters of the specification.
- **Transverse Cracking**
Not included because CDOT used the PG 76-28 binder.

Pavement Management System.

A description of the pavement management system data collection, distresses, and index calculations is in Chapter 3. The summary of results for this project is shown below.

Experimental Project

	Ride Index	Rut Index	LAL Crack Index
Condition Prior To Construction	78	71	58
Condition After Construction	99	100	99
Condition After 1 Year (1999)	90	100	99
Condition After 2 Years (2000)	82	100	81
Condition After 3 Years (2001)	88	100	74

1st Control Project

	Ride Index	Rut Index	LAL Crack Index
Condition Prior To Construction	80	63	38
Condition After Construction	99	100	100
Condition After 1 Year (1999)	91	100	99
Condition After 2 Years (2000)	85	100	96
Condition After 3 Years (2001)	88	100	98

2nd Control Project

	Ride Index	Rut Index	LAL Crack Index
Condition Prior To Construction	65	56	62
Condition After Construction	99	100	99
Condition After 1 Year (1999)	92	96	99
Condition After 2 Years (2000)	84	100	98
Condition After 3 Years (2001)	87	100	98

Project Specific Features:

There were no experimental features on this project.

Lessons Learned:

On the warranty project there was noticeable and extensive longitudinal cracking that developed. The Research Branch took cores from the warranty project at the final Pavement Evaluation Team review in order to gain insight into the determination of the cause(s). There were likely multiple causes, but the lessons learned are summarized below.

- 1) Segregation can manifest in the form of a longitudinal cracks located in or near the wheel path. These distresses were not included as a warrantable item by specification. The specification needs to be re-evaluated to identify the segregation distress thresholds.
- 2) When responsibility is shifted to the contractor, CDOT needs assurances that the contractor is following the accepted quality control plan (both the materials and the constructability aspects). More guidelines and training are needed to define the minimum items in a quality control plan and how CDOT should perform the audit or surveillance role.
- 3) The project selection guidelines need to be followed. The guidelines were developed after this project was selected as a warranty project.

CHAPTER 5: U.S. Highway 36, East and West of Superior Interchange

Experimental and Control Project Information:

The experimental project (warranty) was on U.S. Highway 36 beginning at Cherryvale Road and extended southeasterly for 4.5 miles from Milepost 40.00 to Milepost 44.55. It was in Boulder County. The Colorado Project Number was C 0361-157 (Subaccount No. 11982).

The control project was on I-76 beginning west of Fort Morgan and extended easterly for approximately 16 miles from Milepost 76.5 to Milepost 92.5. It was in Morgan County. The Colorado Project Number was C 0761-170 (Subaccount No. 11979).

A comparison of the information from the experimental (warranty) and control (non-warranty) projects is summarized below. Both of the above projects were built on existing concrete pavements. Both projects were originally in Metric units.

	Experimental 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
10-year Design ESALs	2,586,940	2,800,000
Existing Pavement Structure	8" PCCP & 7" ABC	8" PCCP & 4" EATB

The existing pavement structure was measured prior to the construction project. Both projects had portland cement concrete pavement (PCCP). The experimental project had aggregate base course (ABC) and the control project had emulsified asphalt treated base (EATB). A summary of the existing pavement structure of all projects is shown in Appendix G.

Cost Data:

Contract Costs.

The successful contractor's bid on the warranty project was 102% of the engineer's estimate. The three bids ranged from 102% to 139% of the engineer's estimate. The successful contractor's cost per ton of warranted HBP was \$36.56, which was nearly 100% of the engineer's estimate at \$36.74.

For the control project, the successful contractor's bid was 99% of the engineer's estimate. The three bids ranged from 99% to 124% of the engineer's estimate. The successful contractor's cost per ton of HBP was \$35.38, which was 106% of the engineer's estimate at \$33.34.

The tonnage information for the control project in the following table represents only the quantity of HBP used to construct the specified overlay thickness.

	Experimental Project	Control Project
Tonnage	25,393	77,157
Project Low Bid	\$1,657,140.00	\$4,573,970.60
Engineer's Estimate	\$1,619,248.20	\$4,618,484.00
Low Bid, \$/ton	\$36.56	\$35.38
Engineer's Estimate, \$/ton	\$36.74	\$33.34
Type of Binder	PG 70-34	AC-20R
Warranty Line Item, L.S.	NA	NA
No. of Bidders	3	3

In order to develop the engineer's estimate for the warranty project, 10% was added to the estimated cost per metric ton of warranted HBP. The 10% was developed based on engineering judgment and was intended to cover contractor's costs such as potential risks to perform warranty work, potential lane rental fees because of warranty work, and cost of the warranty bond from bond insurance companies.

Based on the closeness of the cost per metric ton of the engineer's estimate to the successful contractor's low bid in the experimental project, it appeared that the engineer's estimate of the warranty cost of 10% was very reasonable. A detailed cost analysis of all the projects is provided in Chapter 10.

Line Item Profiles for Evaluating Overall Project Cost.

There were 13 bid items that were found to have deviations greater than the default value of +/-1 percent. Construction surveying, mobilization, and WIM station (Type 2) costs were the only three lump sum items in this group. The low bid for construction surveying was only \$5,885 and obviously was not carrying extra cost. The mobilization cost by the low bid was \$55,000 more than the engineer's estimate. The WIM station (Type 2) cost was \$17,185 more than the engineer's estimate. The low bid unit cost per metric ton of HBP (Asphalt)(3-Year Warranty) was only \$0.20 less than the engineer's estimate and the quantity was relatively small at 23,036 metric tons. This would not support the idea that the price was reduced to load up the other items. There was no significant unbalancing of the bid item costs in this contract.

Maintenance Costs.

The Maintenance Management System (MMS) was used to track all of CDOT's maintenance activities on a particular segment of highway. Those included a variety of activities, but of particular interest for this report were those related to the roadway surface (minor patching, machine patching, crack sealing, chip sealing, fog coating, blading shoulder, and base stabilization). The costs of CDOT roadway surface maintenance activities are summarized below for the warranty and control project as gathered in MMS. The Pavement Evaluation Team also identified the costs of the contractor for maintenance performed under the warranty.

	Warranty Project (\$)	Control Project (\$)
CDOT – FY 1999	0	0
Contractor – FY 1999	0	NA
CDOT – FY 2000	0	3,422
Contractor – FY 2000	0	NA
CDOT – FY 2001	0	3,203
Contractor – FY 2001	0	NA
Totals	\$ 0	\$ 6,625

Competition Data:

The bid competitions in warranty and control projects were identical. Both projects had 3 bidders.

Performance Data:

The performance of the experimental and control projects was measured by two methods: the Pavement Evaluation Team (PET) and the pavement management automated data collection van. Measuring pavement distress is very subjective and it is very difficult to get repeatable results. Both of these methods of measurement have advantages and weaknesses. By using both sets of data it was hoped to minimize the chance for errors. Both sets of data are shown below.

Pavement Evaluation Team.

The PET documented the observed distresses that were warranted on the project. They are summarized below.

- Permanent Deformation:
 - August 18, 1999 0mm to 4 mm (avg. 2.1 mm)
 - October 17, 2000 1 mm to 5 mm (avg. 2.3 mm)
 - May 30, 2001 1 mm to 5 mm (avg. 2.9 mm)
 - All measurements were found to be below the threshold levels of the parameters of the specification. The actual ESALs were below the design threshold ESALs.
- Pot Holes:
 - August 18, 1999 small clay ball pop outs in one area
 - October 17, 2000 small clay ball pop outs in one area
 - May 30 , 2001 small clay ball pop outs in one area – within threshold
 - All measurements were found to be below the threshold levels of the parameters of the specification.
- Longitudinal Joint Separation:
 - August 18, 1999 two short areas of hairline cracking observed
 - October 17, 2000 some hairline cracking observed
 - May 30, 2001 hairline cracking almost continuously
 - All measurements were found to be below the threshold levels of the parameters of the specification.

- Raveling and Weathering:
 - August 18, 1999 one small area observed
 - October 17, 2000 one small area observed
 - May 30, 2001 one small area observed
 - All measurements were found to be below the threshold levels of the parameters of the specification.
- Bleeding
 - August 18, 1999 not observed
 - October 17, 2000 not observed
 - May 30, 2001 not observed
 - All measurements were found to be below the threshold levels of the parameters of the specification.
- Delamination of Pavement Layers
 - August 18, 1999 not observed
 - October 17, 2000 not observed
 - May 30, 2001 not observed
 - All measurements were found to be below the threshold levels of the parameters of the specification.
- Transverse Cracking
 - Not included because the contractor used the PG 70-34 binder.

The PET documented the observed distresses on the control project. They are summarized below. Industry elected not to participate in the PET review of this control project. The results are based upon the CDOT and consultant evaluation.

- Permanent Deformation:
 - June 26, 2001 0 mm to 3 mm (avg. 1.30 mm)
 - All measurements were found to be below the threshold levels of the parameters of the specification. Based on ESAL projections, the actual ESALs were below the design threshold ESALs.
- Pot Holes:
 - June 26, 2001 not observed
 - All measurements were found to be below the threshold levels of the parameters of the specification.
- Longitudinal Joint Separation:
 - June 26, 2001 not observed
 - All measurements were found to be below the threshold levels of the parameters of the specification.
- Raveling and Weathering:
 - June 26, 2001 observed at one location

Raveling was observed at one location, approximately M.P. 83.8 in the eastbound roadway. It was an area of about 2 feet wide and 200 feet long that was raveled about 1.5-inches deep.

- Bleeding
June 26, 2001 not observed
All measurements were found to be below the threshold levels of the parameters of the specification.
- Delamination of Pavement Layers
June 26, 2001 not observed
All measurements were found to be below the threshold levels of the parameters of the specification.
- Transverse Cracking
Not included because CDOT used the PG 64-28 binder.

Pavement Management System.

A description of the pavement management system data collection, distresses, and index calculations is in Chapter 3. The summary of results for this project is shown below.

Experimental Project

	Ride Index	Rut Index	LAL Crack Index
Condition Prior To Construction	92	71	100
Condition After Construction	99	100	100
Condition After 1 Year (1999)	97	100	100
Condition After 2 Years (2000)	95	100	100
Condition After 3 Years (2001)	95	100	99

Control Project

	Ride Index	Rut Index	LAL Crack Index
Condition Prior To Construction	65	96	93
Condition After Construction	99	99	100
Condition After 1 Year (1999)	93	98	100
Condition After 2 Years (2000)	88	100	99
Condition After 3 Years (2001)	91	100	96

Project Specific Features:

There were no experimental features on this project.

CHAPTER 6: I-25, North of Pueblo

Experimental and Control Project Information:

The experimental project (warranty) was on I-25, beginning approximately 14 miles north of Pueblo and extended northerly for 5.33 miles from Milepost 114.69 to Milepost 120.02. It was in Pueblo and El Paso Counties. The Colorado Project Number was IM 0251-157 (Subaccount No. 13048).

The control project was on I-25 north of Pueblo and extended for approximately 6.4 miles from Steel Hollow, Milepost 109 to Young Hollow, Milepost 115.4. It was in Pueblo County. The Colorado Project Number was IM 0251-154 (Subaccount No. 12528). This project was also used as the control project for the experimental project on I-25, South of Fountain (Colorado Project Number IM 0252-312, Subaccount No. 12116) Chapter 3 of this report.

Both of the above projects were in English units. A comparison of the information from the experimental (warranty) and control (non-warranty) projects is summarized below.

	Experimental 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
10-year Design ESALs	5,372,000	5,372,000
Existing Pavement Structure	10" HBP & 14" ABC	9.25" HBP & 12" ABC

The existing pavement structure was measured prior to the construction project. Both projects had hot bituminous pavement (HBP) and aggregate base course (ABC). A summary of the existing pavement structure of all projects is shown in Appendix G.

Cost Data:

Contract Costs.

In order to develop the engineer's estimate for the warranty project, approximately \$1 per ton for 71,905 tons of HBP was used to estimate the cost of the warranty line item, which translated into a lump sum of \$75,000. Initially, this dollar amount per ton of HBP was used based on engineering judgment and was intended to cover contractor's costs such as potential risks to perform warranty work, potential lane rental fees because of warranty work, and cost of the warranty bond from bond insurance companies.

The successful contractor's bid on the lump sum cost of the warranty line item was \$50,000, which was about 1% of the total contract cost. The warranty line bid item costs ranged from \$1 to

\$350,000. In estimating the warranty cost for this project, it appears that the successful contractor used approximately \$0.70 per ton of HBP which was about 2% of the cost per ton of HBP.

The successful contractor's bid on the warranty project was 84% of the engineer's estimate. The four bids ranged from 84% to 104% of the engineer's estimate. The successful contractor's cost per ton of warranted HBP was \$35.20, which was 88% of the engineer's estimate at \$40.

For the control project, the successful contractor's bid was 93% of the engineer's estimate. The six bids ranged from 93% to 130% of the engineer's estimate. The successful contractor's cost per ton of HBP was \$32, which was 91% of the engineer's estimate at \$35.

The tonnage information for the control project in the following table represents only the quantity of HBP used to construct the specified overlay thickness.

	Experimental Project	Control Project
Tonnage	71,905	53,422
Project Low Bid	\$4,768,496.39	\$4,634,123.50
Engineer's Estimate	\$5,667,769.30	\$4,992,311.54
Low Bid, \$/ton	\$35.20	\$32
Engineer's Estimate, \$/ton	\$40.00	\$35
Type of Binder	PG 58-28	AC-20R
Warranty Line Item, L.S.	\$50,000	NA
No. of Bidders	4	6

Line Item Profiles for Evaluating Overall Project Cost.

There were 7 bid items that were found to have deviations greater than the default value of +/-1 percent. HBP 3-year warranty and mobilization costs were the only two lump sum items in this group. Both of these items had extended costs that were below the engineer's estimates. There was no unbalancing of bid item costs in this contract.

Maintenance Costs.

The Maintenance Management System (MMS) was used to track all of CDOT's maintenance activities on a particular segment of highway. Those included a variety of activities, but of particular interest for this report were those related to the roadway surface (minor patching, machine patching, crack sealing, chip sealing, fog coating, blading shoulder, and base stabilization). The costs of CDOT roadway surface maintenance activities are summarized below for the warranty and control project as gathered in MMS. The Pavement Evaluation Team also identified the costs of the contractor for maintenance performed under the warranty.

	Warranty Project (\$)	Control Project (\$)
CDOT – FY 2000	---	2,776
Contractor – FY 2000	---	NA
CDOT – FY 2001	0	12,309
Contractor – FY 2001	0	NA
CDOT – FY 2002		
Contractor – FY 2002		NA
CDOT – FY 2003		---
Contractor – FY 2003		---
Totals		\$15,085

Competition Data:

The bid competitions in the warranty and control projects were very similar. The bid competition in the warranty project with four bidders was slightly less than that of the control project with six bidders.

Performance Data:

The performance of the experimental and control projects will be measured by two methods: the Pavement Evaluation Team (PET) and the pavement management automated data collection van.

The PET has not done an evaluation at this time.

Pavement Management System

A description of the pavement management system data collection, distresses, and index calculations is in Chapter 3. The summary of results for this project is shown below.

Experimental Project

	Ride Index	Rut Index	LAL Crack Index
Condition Prior To Construction	84	88	83
Condition After Construction	99	100	100
Condition After 1 Year (2001)	93	100	100
Condition After 2 Years (2002)			
Condition After 3 Years (2003)			

Control Project

	Ride Index	Rut Index	LAL Crack Index
Condition Prior To Construction	79	91	82
Condition After Construction	99	100	100
Condition After 1 Year (2000)	88	100	99
Condition After 2 Years (2001)	90	100	100
Condition After 3 Years (2002)			

Project Specific Features:

On this project the contractor elected to use two special features: recycled asphalt pavement (RAP) and a special longitudinal joint. RAP was used at a rate of 20% in the HBP mix design. The contractor also used a Quality Control plan that included a very high level of testing to ensure good quality and uniformity. The longitudinal construction joint was configured with a step-taper.

CHAPTER 7: I-70, East of Eagle

Experimental and Control Project Information:

The experimental project (warranty) was on I-70 east of Eagle and extended easterly for approximately 11.9 miles from Milepost 147.00 to Milepost 158.90. It was in Eagle County. The Colorado Project Number was IM 0702-222 (Subaccount No. 12731).

The control project was on State Highway 82 beginning approximately 2 miles north of Carbondale, Milepost 10.4 and extended 12.7 miles southeasterly to Milepost 23.1 with two no work sections (M.P. 10.52 to M.P. 14.0 and M.P. 18.0 to M.P. 20.8). The net project length was 6.42 miles. It was in Eagle, Garfield, and Pitkin Counties. The Colorado Project Number was STA 0821-057 (Subaccount No. 13092).

Both of the above projects were in English units. A comparison of the information from the experimental (warranty) and control (non-warranty) projects is summarized below.

	Experimental Project	Control Project
Overlay Thickness	2 inches	2 inches
Rehab 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
10-year Design ESALs	4,288,903	1,197,000
Existing Pavement Structure	8.5" HBP & 8" ABC	6.5" HBP & 6" ABC

The existing pavement structure was measured prior to the construction project. Both projects had hot bituminous pavement (HBP) and aggregate base course (ABC). A summary of the existing pavement structure of all projects is shown in Appendix G.

Cost Data:

Contract Costs.

In order to develop the engineer's estimate for the warranty project, approximately \$1.50 per ton for 102,870 tons of HBP was used to estimate the cost of the warranty line item, which translated into a lump sum of \$155,000. This dollar amount per ton of HBP was used based on engineering judgment and was intended to cover contractor's costs such as potential risks to perform warranty work, potential lane rental fees because of warranty work, and cost of the warranty bond from bond insurance companies.

The successful contractor's bid on the lump sum cost of the warranty line item was \$138,854.84, which was about 2.7% of the total contract cost. The warranty line bid item costs ranged from \$1 to \$138,854.84. In estimating the warranty cost for this project, it appears that the successful

contractor used approximately \$1.35 per ton of HBP which was about 4.2% of the bid cost per ton of HBP. A detailed cost analysis of all the projects is provided in Chapter 10.

The successful contractor's bid on the warranty project was 86% of the engineer's estimate. The four bids ranged from 86% to 104% of the engineer's estimate. The successful contractor's cost per ton of warranted HBP was \$32.50, which was 79% of the engineer's estimate at \$41.

For the control project, the successful contractor's bid was 80% of the engineer's estimate. The three bids ranged from 80% to 89% of the engineer's estimate. The successful contractor's cost per ton of HBP was \$37.80, which was 75% of the engineer's estimate at \$50.50. Since the asphalt cement for each HBP grading was paid for separately from the aggregates, these costs per ton of HBP were not obtained directly from the bid tabulation but were calculated manually. The calculation procedure involved summing all the extended costs of the HBP grading and the asphalt cements used from the bid tabulation. To obtain the composite unit cost for the HBP mix (aggregates and asphalt cement), this sum is divided by the total tonnage of the HBP grading given in the bid tabulation.

The tonnage information for the control project in the following table represents only the quantity of HBP used to construct the specified overlay thickness.

	Experimental Project	Control Project
Tonnage	102,870	40,294
Project Low Bid	\$5,223,168.97	\$2,271,045.70
Engineer's Estimate	\$6,106,789.50	\$2,842,237.00
Low Bid, \$/ton	\$32.50	\$34.84 / \$37.85
Engineer's Estimate, \$/ton	\$41.00	\$47.54 / \$50.55
Type of Binder	PG 58-22	PG 58-28 / PG 64-28
Warranty Line Item, Low Bid	\$138,854.84	NA
No. of Bidders	4	3

Line Item Profiles for Evaluating Overall Project Cost.

There were 6 bid items that were found to have deviations greater than the default value of +/-1 percent. HBP 3-yr warranty and mobilization costs were the only two lump sum items in this group. The HBP 3-yr warranty cost was less than the engineer's estimate and obviously was not carrying unreasonable extra cost. The low bid mobilization cost was \$125,000 more than the engineer's estimate. Based on the mobilization costs submitted by all the other bidders, the low bid of \$425,000 was reasonable and was not indicating a case of front-end loading. There was no significant unbalancing of bid item costs in this contract.

Maintenance Costs.

The Maintenance Management System (MMS) was used to track all of CDOT's maintenance activities on a particular segment of highway. Those included a variety of activities, but of particular interest for this report were those related to the roadway surface (minor patching, machine

patching, crack sealing, chip sealing, fog coating, blading shoulder, and base stabilization). The costs of CDOT roadway surface maintenance activities are summarized below for the warranty and control project as gathered in MMS. The Pavement Evaluation Team also identified the costs of the contractor for maintenance performed under the warranty.

	Warranty Project (\$)	Control Project (\$)
CDOT – FY 2001	0	2,209
Contractor – FY 2001	0	NA
CDOT – FY 2002		
Contractor – FY 2002		NA
CDOT – FY 2003		
Contractor – FY 2003		NA
Totals		

Competition Data:

The bid competitions in the warranty and control projects were very similar. The bid competition in the warranty project with four bids was slightly better than that of the control project with three bidders.

Performance Data:

The performance of the experimental and control projects will be measured by two methods: the Pavement Evaluation Team (PET) and the pavement management automated data collection van.

The PET has not done an evaluation at this time.

Pavement Management System

A description of the pavement management system data collection, distresses, and index calculations is in Chapter 3. The summary of results for this project is shown below.

Experimental Project

	Ride Index	Rut Index	LAL Crack Index
Condition Prior To Construction	85	81	91
Condition After Construction	99	100	100
Condition After 1 Year (2001)	88	100	100
Condition After 2 Years (2002)			
Condition After 3 Years (2003)			

Control Project

	Ride Index	Rut Index	LAL Crack Index
Condition Prior To Construction	92	69	90
Condition After Construction	99	99	100
Condition After 1 Year (2001)	95	96	99
Condition After 2 Years (2002)			
Condition After 3 Years (2003)			

Project Specific Features:

A test section was performed on the longitudinal joint construction. Joint tape is a new product that is placed on the cold side of a joint. When the hot side is paved, the tape melts and seals the joint.

Another test section that included Trinidad Lake Asphalt was placed on the project in preparation for the next year's paving in Glenwood Canyon.

Lessons Learned:

On the warranty project the contractor elected to use a type of binder and an asphalt content that were different from what CDOT would normally choose. This created quite a bit of discussion and resulted in the following lessons learned.

- 1) When shifting responsibility from CDOT to the contractor, there is a question of how much responsibility should be shifted. CDOT is receiving a 3-year warranty. In exchange, the contractor selects the type of binder and asphalt content, amongst other things. If CDOT would normally use 5.4% asphalt content with a polymer-modified binder and the contractor elects to use 4.9% and an unmodified binder, the current specification finds this acceptable. However, it is not clear if a 3-year warranty is sufficient exchange. The amount of responsibility shifted to the contractor in exchange for a 3-year warranty needs to be re-evaluated.
- 2) When responsibility is shifted to the contractor, CDOT needs assurances that the contractor is following the accepted quality control plan (both the materials and the constructibility aspects). More guidelines and training are needed to define the minimum items in a quality control plan and how CDOT should perform the audit or surveillance role.

CHAPTER 8: U.S. 50, East of Kannah Creek

Experimental and Control Project Information:

The experimental project (warranty) was on U.S. 50 (strategic corridor southeast of Grand Junction) east of Kannah Creek and extended southeasterly for approximately 7.3 miles from Milepost 46.05 to Milepost 53.34. It was in Mesa and Delta Counties. The Colorado Project Number was NH 0501-038 (Subaccount No. 12153).

The control project was on U.S. 50 (adjacent to and northwest of the warranty project), southeast of Whitewater, beginning at Milepost 42.0 and extended for 4 miles southeasterly to Milepost 45.95. It was in Mesa County. The Colorado Project Number was SP 0501-037 (Subaccount No. 11838).

Both of the above projects were originally in Metric units. A comparison of the information from the experimental (warranty) and control (non-warranty) projects is summarized below.

	Experimental Project	Control Project
HBP 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	Under Construction	May 9, 2000
Facility Type	4-lane National Highway	4-lane National Highway
20-year Design ESALs	3,743,000	3,743,000
Existing Pavement Structure	N / A	N / A

There was no existing pavement structure prior to the construction project. These were evaluated as new construction.

Cost Data:

Contract Costs.

In order to develop the engineer's estimate for the warranty project, approximately \$1.33 per ton for 60,332 tons of HBP was used to estimate the cost of the warranty line item that translated into a lump sum of \$80,000. This dollar amount per ton of HBP was used based on engineering judgment and was intended to cover contractor's costs such as potential risks to perform warranty work, potential lane rental fees because of warranty work, and cost of the warranty bond from bond insurance companies.

In estimating the warranty cost for this project, the contractor used approximately \$1.66 per ton of HBP which was about 5.7% of the bid cost per ton of HBP. The lump sum cost of the warranty line item was \$100,000, which was about 0.80% of the total contract cost. The warranty line bid item costs ranged from \$20,000 to \$100,000.

The successful contractor's bid on the warranty project was 91% of the engineer's estimate. The five bids ranged from 91% to 117% of the engineer's estimate. The successful contractor's cost per ton of warranted HBP was \$29.03, which was 73% of the engineer's estimate at \$39.92.

For the control project, the successful contractor's bid was 91% of the engineer's estimate. The five bids ranged from 91% to 108% of the engineer's estimate. The successful contractor's cost per ton of HBP was \$28.67, which was 93% of the engineer's estimate at \$30.77. Since the asphalt cement for each HBP grading was paid for separately from the aggregates, these costs per ton of HBP were not obtained directly from the bid tabulation but were calculated manually. The calculation procedure involved summing all the extended costs of the HBP grading and the asphalt cements used from the bid tabulation. To obtain the composite unit cost for the HBP mix (aggregates and asphalt cement), this sum is divided by the total tonnage of the HBP grading given in the bid tabulation.

The tonnage information for the experimental project in the following table represents only the quantity of warranted HBP that was placed only in the eastbound lanes. The tonnage information for the control project represents only the quantity of HBP used to construct the specified thickness of HBP for both eastbound and westbound lanes.

	Experimental Project	Control Project
Tonnage	60,332	69,408
Project Low Bid	\$12,585,731.63	\$6,416,695.85
Engineer's Estimate	\$13,850,414.40	\$7,053,989.30
Low Bid, \$/ton	\$29.03	\$26.55 / \$31.15
Engineer's Estimate, \$/ton	\$39.92	\$28.62 / \$33.62
Type of Binder	PG 76-28	PG 58-28/PG 70-34
Warranty Line Item, Low Bid	\$100,000	NA
No. of Bidders	5	5

Line Item Profiles for Evaluating Overall Project Cost.

There were 11 bid items that were found to have deviations greater than the default value of +/-1 percent. Clearing and grubbing and mobilization costs were the only two lump sum items in this group. Both of these items had extended costs that were below the engineer's estimates. There was no unbalancing of bid item costs in this contract.

Maintenance Costs.

The Maintenance Management System (MMS) was used to track all of CDOT's maintenance activities on a particular segment of highway. Those included a variety of activities, but of particular interest for this report were those related to the roadway surface (minor patching, machine patching, crack sealing, chip sealing, fog coating, blading shoulder, and base stabilization). The costs of CDOT roadway surface maintenance activities are summarized below for the warranty and control project as gathered in MMS. The Pavement Evaluation Team also identified the costs of the contractor for maintenance performed under the warranty.

	Warranty Project (\$)	Control Project (\$)
CDOT – FY 2001	----	27
Contractor – FY 2001	----	NA
CDOT – FY 2002		
Contractor – FY 2002		NA
CDOT – FY 2003		
Contractor – FY 2003		NA
CDOT – FY 2004		----
Contractor – FY 2004		----
Totals		

Competition Data:

The bid competitions in the warranty and control projects were identical. Both the warranty and control projects had five bidders.

Performance Data:

The performance of the experimental and control projects will be measured by two methods: the Pavement Evaluation Team (PET) and the pavement management automated data collection van.

The PET has not done an evaluation at this time.

Pavement Management System

A description of the pavement management system data collection, distresses, and index calculations is in Chapter 3. The summary of results for this project is shown below.

Experimental Project

	Ride Index	Rut Index	Crack Index
Condition Prior To Construction	NA	NA	NA
Condition After Construction	NA	NA	NA
Condition After 1 Year (2002)			
Condition After 2 Years (2003)			
Condition After 3 Years (2004)			

Control Project

	Ride Index	Rut Index	Crack Index
Condition Prior To Construction	NA	NA	NA
Condition After Construction	NA	NA	NA
Condition After 1 Year (2001)	94	100	100
Condition After 2 Years (2002)			
Condition After 3 Years (2003)			

Project Specific Features:

At this time, there is not any information regarding the use of project specific features.

CHAPTER 9: Surveys of CDOT's and Contractor's Representatives

As the Cost Benefit Evaluation Committee (CBEC) gathered data for this report, it became clear that more data would be needed than what we had readily available from the standard plans and cost estimate documents. In order to include as much pertinent information as possible and minimize the gaps in the data we had to conduct the evaluation, it was decided to survey individuals familiar with the project. The CBEC conducted two formal surveys.

Survey No. 1 – Project Specific Information:

Purpose.

The purpose of this survey was to query CDOT and contractor project personnel to ensure that any information that they had available could be considered in this evaluation. This survey was conducted in writing, but the participants were contacted by phone prior to the survey being sent. The summaries of responses from CDOT and the contractor are in Appendix H.

Findings.

At this time there were 6 projects awarded, 5 of which were completed. These responses are from the 5 that were completed.

- support for continued use of project selection guidelines and pre-ad constructibility reviews (CDOT and contractor)
- regarding the Quality Control Plan there was great variability in their content, use, process to address deviations, and the audit procedure (CDOT and contractor)
- responsibility for binder grade selection and the appropriate risk allocation should be reviewed by the warranty task force (CDOT)
- adequacy of specification for long-term performance of the pavement is still a question (CDOT)
- CDOT and the contractors commented upon the level of attention paid to quality on the 5 projects constructed at this time. From CDOT project personnel's perspective, 5 of the 5 projects had equal or better attention to quality with testing and quality control, while 3 of the 5 projects had equal or better attention to quality from constructibility. From the contractors' perspective 2 contractors had greater attention to quality than they would on a typical CDOT project and 3 contractors had the same.
- permanent stationing to benefit the Pavement Evaluation Team (PET) (CDOT)

Survey No. 2 – Contractors' Initial Cost Data:

Purpose.

The purpose of this survey was to determine the cost that the successful contractors used to value the warranty at the time of bidding. As the CBEC tried to determine the cost implications of including a warranty in a project specification, one technique used was to ask the contractors directly. The contractors' representatives were surveyed by telephone. The individual responses were kept confidential but the summary of responses is shown below.

Findings.

At this time there were 6 projects awarded, 5 of which were completed. These responses are from all 6 that were awarded.

- 3 contractors did not consider additional costs for the warranty and 3 contractors added a little additional cost for potential maintenance, bonding, and unknown risk.
- 3 contractors used a higher quality material than they normally would have and 3 contractors used their standard quality.
- 3 contractors performed more process control and 3 contractors used their standard process control
- with the same specifications and circumstances, 3 contractors would not have done anything differently and 3 contractors would have done something different. The differences were: include less money for future maintenance, include more money, and analyze the pavement design differently.

Summary:

1. The contractor's Quality Control Plan was in place for all of the projects. These plans differed greatly. Also, CDOT's audit or surveillance process of the plan was not uniform from project to project. Some projects had greater levels and other lesser levels. It appears that more training in this area is needed. Some additional language should be developed in the specification to define the Quality Control Plan and, in particular, how deviations are to be addressed.
2. During construction, contractors indicated that all 5 projects had an equal or greater level of attention to quality than normal projects. CDOT indicated that all 5 projects had equal or greater level of attention to testing and quality control than normal projects, and 3 of the 5 projects had equal or greater level of attention to constructibility.
3. Most of the contractors (primarily the major ones) have internal Quality Control (QC) operations that are very good. This is a result of the QC / QA initiative that started about 10 years ago. When a contractor with a fully developed QC operation constructed a warranty project, there was not much change in that contractor's quality control practice for testing and constructibility. However, since these were the first warranty projects, there was very likely some level of additional attention to detail in all of the projects.
4. The warranty task force should reconvene to evaluate the areas of concern that developed after the construction of these 5 projects.

CHAPTER 10: Cost Analysis

Limitations:

In order to determine the cost of the warranty, many projects were needed. The more projects available for analysis, the more accurate the determination would be. The analysis presented here was limited because there were only a few projects. It is important to understand all of these limitations when discussing the results of the analysis.

- There were only a few projects on which to base the analysis. The cost analysis of the warranty may not be significant because it was based on the few projects available.
- The first set of projects would likely tend to have more variable costs. This was a new concept and there was not much clarity or experience regarding the risk of warranty and the enforcement of warranty. As time goes on and there are more projects, the variability will likely decrease. However, the variability in these few projects may have skewed the analysis.
- Lump sum items were a good place to include many things, for example the lump sum warranty line item. We may likely never know what was included in the lump sum items - despite the fact that we assumed that the lump sum included only the warranty. This was a limitation in this analysis, but it was unknown how to correct it.

Initial Cost Analysis:

Summaries of the item costs on the projects evaluated to date are shown in Figure 1. These were all on the warranted HBP item and included Engineer's Estimate, each contractor's bid, the annual Region average, and the control project low bid.

Since it was very difficult to determine the actual initial cost of the warranty, several different analyses were performed to determine an estimate.

Based on Expert Opinion.

The members of the Cost Benefit Evaluation Committee reviewed the cost data on the warranty and non-warranty projects. Overall project costs and individual item costs were examined. Based upon this visual and subjective evaluation, the cost of warranty projects was determined to be negligible.

Based on Contractor Interviews.

Three contractors did not consider additional costs for the warranty, and 3 contractors added a little additional cost for potential maintenance, bonding, and unknown risk. Based on phone interviews with the contractors, there was no to very little additional cost added for the short-term warranty.

Based on Engineer's Estimate.

For the first three projects constructed in 1998, the Engineer's Estimate included cost per ton of the HBP and an additional 10% for the warranty. The additional 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 the cost of warranty bond from bond insurance companies.

This analysis assumed that the low bidder's cost for the Item 403 HBP also included the warranty cost. The low bidder's cost in excess of 90% of the Engineer's Estimate was assumed to be the cost of the warranty. These costs expressed as dollars and percentages of the basis (the engineer's estimate) are shown below.

	I-25, S. of Fountain	US-36 at Superior	C-470 at Santa Fe	Averages
Engineer's Est. of HBP (\$ / ton)	40.82	36.74	38.10	-
0.9 * Eng. Est. of HBP (\$ / ton)	36.74	33.07	34.29	-
Warranty Low Bid of HBP (\$/ ton)	35.38	36.56	37.19	-
Warranty Cost (\$ / ton)	-1.36	3.49	2.90	\$1.68 / ton
Warranty Cost (%)	-3.7	10.6	8.5	5.1 %

Based on this analysis of three projects, the warranty cost was estimated to be \$1.68 per ton of HBP or 5.1% of the Engineer's Estimate of the cost of HBP.

Based on Lump Sum Bid of Warranty.

For the next three projects, the warranty was bid as a lump sum line item. For this analysis it was assumed that the cost of the warranty was included exclusively in the lump sum item.

	I-25 N. of Pueblo	I-70 at Eagle	US-50 at Kannah Cr	Averages
HBP Low Bid (\$ / ton)	35.20	32.50	29.03	-
Lump Sum for Warranty (\$)	50,000	138,000	100,000	-
Project Quantity (ton)	71,905	102,870	60,332	-
Warranty Cost (\$ / ton)	0.70	1.34	1.66	\$1.23 / ton
Warranty Cost (%)	2.0	4.1	5.7	3.9 %

Based on this analysis of three projects, the warranty cost was estimated to be \$1.23 per ton of HBP or 3.9% of the low bidder's cost of HBP.

Based on Annual Region Average Cost of HBP.

The annual Region average cost of HBP with the same binder grade was calculated. The binder grade was considered important because it can impact the cost of the HBP by approximately \$5 / ton depending on whether it is polymer modified or not. These annual Region averages were compared to the low bidders' cost per ton on the first three projects. For this analysis, the difference was assumed to be the cost of the warranty.

Based on this analysis of three projects, the warranty cost was estimated to be -\$1.29 per ton of HBP or -3.3% of the cost of the annual Region average HBP with the same binder grade. The negative values indicated that the warranty project was less expensive than the annual Region average costs.

	I-25, S. of Fountain	US-36 at Superior	C-470 at Santa Fe	Averages
Annual Region Average (\$ / ton)	35.36	39.58	38.05	-
Warranty HBP Low Bid (\$ / ton)	35.38	36.56	37.19	-
Warranty Cost (\$ / ton)	0.02	-3.02	-0.86	-\$1.29/ ton
Warranty Cost (%)	0.1	-7.6	-2.3	-3.3 %

This analysis was also performed on the three projects that were advertised with the warranty cost included as a lump sum. For this analysis, the cost of the warranty was calculated as the difference of the annual Region average cost of HBP with the same binder grade (this would not include any warranty costs) from the sum of the HBP low bid and the lump sum of the low bid warranty cost.

	I-25 N. of Pueblo	I-70 at Eagle	US-50 at Kannah Cr	Averages
HBP Low Bid (\$ / ton)	35.20	32.50	29.03	-
Lump Sum for Warranty (\$ / ton)	0.70	1.34	1.66	-
Annual Region Average (\$ / ton)	40.57	42.58	43.31	-
Warranty Cost (\$ / ton)	-4.67	-8.74	-12.62	-\$8.68/ ton
Warranty Cost (%)	-11.5	-20.5	-29.14	-20.4 %

Based on this analysis of three projects, the warranty cost was estimated to be -\$8.68 per ton of HBP or -20.4% of the cost of HBP. The negative values indicated that the warranty project was less expensive than the annual Region average costs.

Based on Control Project.

For the first three projects constructed in 1998, the HBP item cost for the control projects were compared to those of the warranty projects.

	I-25, S. of Fountain	US-36 at Superior	C-470 at Santa Fe	Averages
Control Project HBP Cost (\$ / ton)	32.00	35.38	45.13*	-
Warranty HBP Cost (\$/ton)	35.38	36.56	37.19	-
Warranty Cost (\$ / ton)	3.38	1.18	-7.94	-\$1.13/ ton
Warranty Cost (%)	10.6	3.3	-17.6	-1.2 %

* - average of both control projects

Based on this analysis of three projects, the warranty cost was estimated to be -\$1.13 per ton of HBP or -1.2% of the cost of HBP used on the control project. The negative values indicated that the warranty project was less expensive than the control project HBP costs.

This analysis was also performed on the three projects that were advertised with the warranty cost included as a lump sum. For this analysis, the cost of the warranty was calculated as the difference

of the cost of HBP on the control project (this would not include any warranty costs) from the sum of the HBP low bid and the lump sum of the low bid warranty cost.

	I-25 N. of Pueblo	I-70 at Eagle	US-50 at Kannah Cr	Averages
Warranty HBP Cost (\$ / ton)	35.20	32.50	29.03	-
Lump Sum for Warranty (\$ / ton)	0.70	1.34	1.66	-
Control Project HBP Cost (\$ / ton)	32.00	34.84	31.15	-
Warranty Cost (\$ / ton)	3.90	-1.00	-0.46	\$0.81/ ton
Warranty Cost (%)	12.2	-2.9	-1.5	2.6 %

Based on this analysis of three projects, the warranty cost was estimated to be \$0.81 per ton of HBP or 2.6% of the cost of HBP used on the control project.

Based on Average Cost of Item 403 for All Bidders.

In analyzing the cost data for the low bid item, it was very noticeable that the low bidder had a more favorable price for the HBP item than the unsuccessful bidders. An analysis was done using the average of the bids on the Item 403, HBP.

For the first three projects constructed in 1998, the average HBP item cost of all bidders was compared to the control projects.

	I-25, S. of Fountain	US-36 at Superior	C-470 at Santa Fe	Averages
Average of All HBP Bids on Control Project (\$ / ton)	38.33	37.19	46.23*	-
Average of All HBP Warranty Bids (\$ / ton)	38.54	43.94	40.55	-
Warranty Cost (\$ / ton)	0.21	6.75	-5.68	\$0.43 / ton
Warranty Cost (%)	0.6	18.2	-12.3	2.2 %

* - average of both control projects.

Based on this analysis of three projects, the warranty cost was estimated to be \$0.43 per ton of HBP or 2.2% of the HBP cost on the control project.

This analysis was also performed on the three projects that were advertised with the warranty cost included as a lump sum. For this analysis, the cost of the warranty was calculated as the difference of the cost of HBP on the control project (this would not include any warranty costs) from the sum of the HBP low bid and the lump sum of the low bid warranty cost.

Based on this analysis of three projects, the warranty cost was estimated to be \$1.15 per ton of HBP or 4.5% of the cost of HBP used on the control project.

	I-25 N. of Pueblo	I-70 at Eagle	US-50 at Kannah Cr	Averages
Average of All HBP Bids on Warranty Project (\$ / ton)	38.43	37.38	36.31	-
Average for All Warranty Lump Sum (\$/ ton)	1.73	0.63	0.98	-
Average of All HBP Bids on Control Project (\$ / ton)	38.33	42.36	31.33	-
Warranty Cost (\$ / ton)	1.83	-4.35	5.96	\$1.15/ ton
Warranty Cost (%)	4.8	-10.3	19.0	4.5 %

Although this particular analysis shows that there could be a significant cost for the associated short-term warranties, the CBEC does not believe that this will manifest for several reasons. 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. CDOT got a good price from the successful low bidder because the project fit the contractor's schedule, goals, etc. The unsuccessful bidders likely had conflicts, or they looked at the risks of the warranty differently.

Based on Overall Project Cost.

It was important to consider the overall project cost when evaluating the cost of the warranty. When the contractor bids a project, the warranty cost may not entirely be in HBP item. The costs may be located elsewhere in the bid. From the owner's perspective there is a concern because of a potentially unbalanced bid. From the contractor's perspective, this could easily occur due to differing business practices between contractors.

Analysis of each warranty project for unbalanced bids was conducted in this report. The line item profiles for each of the warranty projects were obtained from the CDOT Cost Estimating Unit. The line item profile graph for each project bid by CDOT is currently generated by the AASHTO Trns*port software used by the Cost Estimating Unit Decision Support System (DSS). This graph is used to identify those bid items most responsible for bidding deviations. These items can then be examined to determine the cause(s) of deviations that may include unbalanced bidding, front-end loading, complementary bidding, inaccurate bidding, and a combination of two or more of these causes.

To detect possible bidding irregularities using the line item profile analysis, each bid item for a given contract is analyzed by comparing its unit and extended costs (quantity x unit cost) with that of the Engineer's Estimate. The deviation of each item's extended cost from the engineer's estimate expressed as a percentage of the total project cost as estimated by the engineer will be plotted in the line item profile if it exceeds a certain value specified in the program. By default, CDOT is using a minimum of +/-1 percent deviation from the baseline, which is the engineer's estimate. If for any reason, the deviation of any bidder's item extended prices from the engineer's

estimate is greater than +/-1 percent of the engineer's estimate of the total project cost, this item will be included as one of the items to be plotted in the line item profile.

Example: The reference prices are the engineer's estimate item bids. Suppose the engineer's estimate for the total cost of a project is 1,000,000 and there are a total of three bidders. The engineer's estimate and the bids on 5,000 tons of hot bituminous pavement (HBP) are as follows:

	<u>Unit Cost</u>	<u>Extended Price</u>
Engineer's Estimate	\$ 35	\$ 175,000
Low Bidder	\$ 36	\$ 180,000
2 nd Low Bidder	\$ 40	\$ 200,000
3 rd Low Bidder	\$ 45	\$ 225,000

The engineer's estimate as the baseline is the default setting in the Trns*port DSS software. The low bidder is \$ 5,000 more than the engineer's estimate and will be plotted as +0.50 % ($5,000/1,000,000 \times 100$). Although, this deviation is less than +/-1 percent (the default value used to determine whether an item has to be included or excluded in further evaluation), the HBP bid item will be included in the line item profile as one of the items under investigation because at least one bidder's deviation from the engineer's estimate exceeds +/-1 percent. The 2nd and 3rd low bidders have +2.5% ($25,000/1,000,000 \times 100$) and +5.0% ($50,000/1,000,000 \times 100$) deviations from the engineer's estimate of total project cost.

The line item profile analysis was used on warranty projects to determine items with significant deviations from the engineer's estimate and to evaluate if there is some degree of unbalancing in the bid item prices. The results of the analysis for the individual projects are in the Chapter with that project. In general, there was no significant degree of bid item cost unbalancing in all warranty projects that were examined.

Summary.

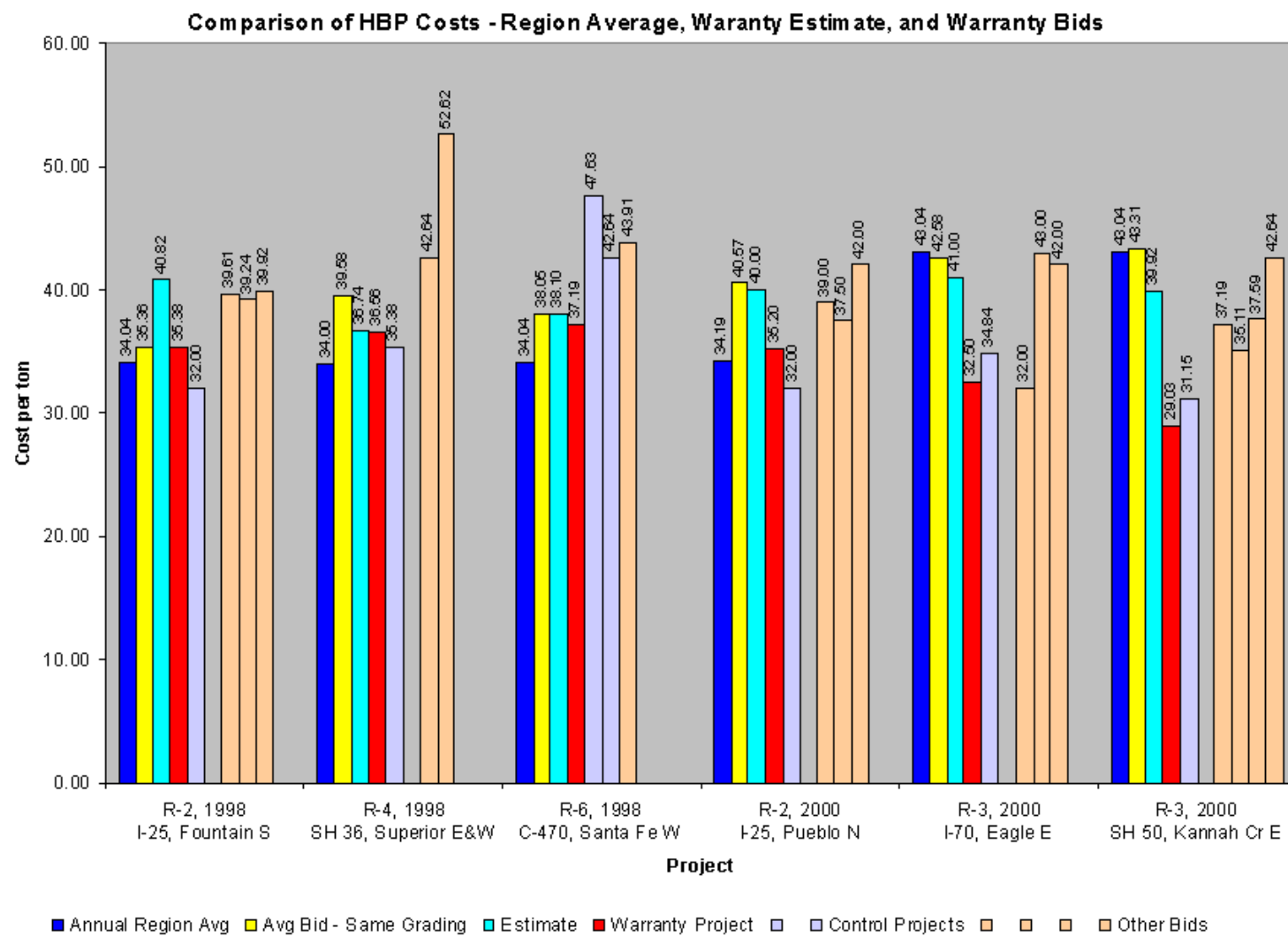
- 1) The initial cost was objectively analyzed 4 different ways using the 6 projects available at this time. The average initial cost from those 24 analyses is that warranties cost \$ -0.85 per ton or -1.6%. Subjective evaluation by the Cost Benefit Evaluation Committee and the survey of the contractors on these 6 projects indicated that the initial warranty cost was negligible. Considering the variability in the data and the limited number of projects, at this time the initial cost of the 3-year warranty was considered negligible.
- 2) There is limited data to compare the cost of a warranty on new construction versus an overlay. The only project that was new construction was on U.S. 50 at Kannah Creek. With the limited data, the cost of the warranty on new construction is slightly less expensive than overlays. The key point should be the scoping of the project. If the rehabilitation selected is appropriate, then the risk and associated cost will likely be negligible.
- 3) The selection of binder grading merits some discussion. On 5 of the 6 projects, the contractor used the low-temperature binder grading recommended by CDOT. This meant that CDOT was responsible for the thermal cracking on 5 of the projects. On the 6th project the contractor used

an inferior low-temperature grade of binder and also took the responsibility for filling the transverse cracks.

CDOT had no requirements for the selection of the high temperature binder grade. The warranty specification required the contractor to perform remedial action when the rutting was greater than 8 mm in depth. There are several options a contractor has to develop a rut-resistant mixture. These options include modification of the binder, angular aggregates, a good gradation, and others. It is not absolutely necessary to have polymer modification to resist rutting, but that is one option.

Using a binder that has a lower grade is not synonymous with a pavement that has a lower quality. When a contractor takes on the responsibility for creating a quality mix design, binder grading is only one of several factors used to create a quality mix design. With the proper engineering, it is not necessary the binder be polymer modified to get the best value.

- 4) Two methods of supplying bids were used to evaluate the initial cost of the warranty. One of the methods included the warranty cost with the Item 403 and the other method had the warranty cost as a line item. Regardless of the method, it appears the cost analysis produced similar results. It was easier to perform the cost analysis with the separate line item. It was recommended to continue using the separate line item.



Maintenance Cost Analysis:

The maintenance costs are summarized for the 3 warranty projects that have had the warranty term expire. Also, the maintenance costs for the four control projects corresponding to those warranty are shown.

	Warranty	Control
Region 2	\$ 0*	\$ 15,085
Region 6	\$ 0*	\$ 2,187 (#1) \$ 913 (#2) \$ 1,550 (Avg.)
Region 4	\$ 0	\$ 6,625

* Maintenance was performed by the contractor on these 2 projects at no cost to CDOT. It was part of the warranty work.

The warranty projects had no maintenance costs for CDOT. The contractor was required to perform maintenance on 2 of the 3 projects. These maintenance costs are not known at the time of this report.

For the control projects, the average cost of maintenance per project was \$7,753. The maintenance costs of the control projects average \$2,500 per year over 3 years and is considered insignificant. It should be noted that there is limited data to draw a conclusion with the maintenance costs.

Pavement Evaluation Team Cost Analysis:

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. Traffic control for the evaluation was provided by CDOT Maintenance and estimated to be \$1000 per site for time and equipment.

Each time the Pavement Evaluation Team reviewed the pavement, the total of all costs was approximately \$5,400. This evaluation would likely occur once per warranty project, so the cost is estimated at \$5,400 per project.

Personnel	Hours	Hourly Rate* (\$ / hr)	Cost (\$)
Consultant	Lump Sum		2,500
Industry Rep.	8	80.00	640
P.E. II	8	55.00	440
P.E. I	8	50.00	400
E.I.T. II	8	45.00	360
G.P. II (DTD)	2	30.00	60
Maintenance (Traffic Control)	Lump Sum		1,000
Total			\$ 5,400

* A loading factor of 1.35 was used to calculate the CDOT hourly rates.

Weigh-in-Motion Station Cost Analysis:

The initial cost of each weigh-in-motion (WIM) station was approximately \$50,000. The annual maintenance cost was approximately \$10,000 or \$30,000 over the 3-year term of the warranty. The total cost for the WIM station was \$80,000 per project with a three-year warranty.

For a 5-year warranty, there is an additional cost of site repairs that is approximately \$14,000 at the five-year point. The total cost for the WIM station was \$114,000 with a five-year warranty.

It should be noted that the WIM is required for the warranty but will have additional value for future development of design traffic data.

Weigh-In-Motion Station Approximate Cost

ITEM	VALUE	COMMENTS
Initial Construction and Equipment costs (4 lane road)		
2 Class 1 piezos per lane	\$16,000	Includes Installation
1 Loop per lane	\$8,000	Includes Installation
WIM Computer and station	\$26,000	Includes all appurtenances
Total =	\$50,000	
Annual Site Maintenance		
Piezoes-resin repair	\$800	Does not include pavement repairs
Loops-epoxy repair	\$400	Does not include pavement repairs
WIM Electronics before 5 years	\$100	After 5 years use \$300/year
Phone and Electric	\$900	
Traffic Control	\$2,500	

Site Calibration (consultant)	\$3,500	Includes Calibration truck
Total =	\$8,200	
Annual Staffing		
60 hours of a EPST I for site visits @ \$14.00/hour	\$840	Without loading factor of 1.42
60 hours of a EPST II for data reduction @ \$17.50/hour	\$1,050	Without loading factor of 1.42
10 hours of a PE I for monthly and annual reports @ 30.00/hour	\$300	Without loading factor of 1.42
Total =	\$2,190	
Site Repairs		
1 Piezo every 5 years	\$4,000	Includes Installation
1 Loop every 5 years	\$2,000	Includes Installation
WIM Electronics after 5 years	\$8,000	
Total =	\$14,000	

It should be noted that this could have a rather large impact on CDOT's overall weigh-in-motion program. Assuming that these 3-year warranties become fully implemented, it is estimated that there could be 2 projects per Region per year or a total of 12 projects per year statewide. The costs for each of the first three years are shown below. At the third year the cost would continue annually as long as the warranty program continues. As 12 warranty sites are added in year 4, 12 would be retired from year 1. The annual cost of the WIMs would be approximately \$1 million per year.

<u>Year</u>	<u>Projects</u>	<u>Total WIM</u>	<u>Installation</u>	<u>Maint. & Oper.</u>	<u>Total</u>
1	12	12	\$600,000	\$120,000	\$720,000
2	12	24	\$600,000	\$240,000	\$840,000
3	12	36	\$600,000	\$360,000	\$960,000
4	12	36	\$600,000	\$360,000	\$960,000

Construction Engineering Cost Analysis:

One of the warranty projects had no tester and reduced inspection. This resulted in a reduction to the Construction Engineering Costs for that particular project. Due to the nature of the Construction Engineering Pool, it was not possible to gather construction-engineering costs for the warranty and control projects in order to make a comparison.

Currently, the QA process is not clearly defined in the warranty specification. This process needs better definition. Once the QA process is clearly defined, a comparison of the construction engineering costs in the control projects as compared to the warranty projects will be possible.

Summary of Cost Analysis:

The summary of the overall additional cost analysis for the 3-year pavement warranty projects as compared to the control projects is shown below:

Item	Cost Differential per Project
Initial Bid (based on 6 projects)	Negligible
Maintenance (based on 3 projects)	Negligible
Pavement Evaluation Team	\$ 5,400
Weigh-In-Motion Station	\$ 80,000
Total	\$ 85,400

Based on the information from the 6 warranty projects that were available at this time, the overall additional cost of a warranty project with a 3-year term was estimated to be approximately \$ 85,400. The approximate cost of a warranty project was \$3 million. The additional cost is approximately 3% of the overall project cost.

It should be noted that \$80,000 of the additional \$85,400 can be directly attributed to the cost of the weigh-in-motion station.

Assuming full implementation would include about 2 projects per Region per year, there would be 12 projects per year. The total cost would equate to approximately \$1 million per year. This is predominately from the weigh-in-motion stations.

CHAPTER 11: Benefit Analysis

Competition Analysis:

Based on the six projects awarded to date, there has been an average of 3.7 bidders on each of the experimental warranty projects and an average of 3.7 on each of the control projects. Overall, the bid competition in experimental and control projects is almost identical. Based on the availability of relatively similar projects for comparison, two control projects have been used for the warranty project on C-470 between Santa Fe and Wadsworth Blvd. and only one control project has been used for two warranty projects on I-25 at Fountain-South and North of Pueblo. A total of six **unique** control projects have been used in comparing with warranty projects. The number of bidders for the experimental and warranty projects is tabulated below.

	Number of Bidders	
	Experimental	Control
I-25 @ Fountain	4	6*
C-470 @ Santa Fe	2	2 and 3
US-36 @ Superior	3	3
I-25 @ Pueblo	4	6*
I-70 @ Eagle	4	3
US-50 @ Kannah	5	5

* These are the same control projects.

There have been a total of 22 bids received on these 6 warranty projects. Of the 22 bids there have been 10 different contractors. Of the successful bidders on the six projects, there have been 5 different paving contractors.

By comparison, there have been a total of 22 bids received on the 6 control projects. Of these 22 bids, there have been 11 different contractors. Of the successful bidders on the six control projects, there have been 5 different paving contractors.

Performance Analysis:

The performance analysis was determined using two methods. One was using the results of the Pavement Evaluation Team (PET) and the other using the results of the Pavement Management System (PMS).

Using the results of the PET, there seems to be little difference in performance of the control and warranty projects. Two of the warranty projects had longitudinal joint separation that needed maintenance and the third required no maintenance. Two of the control projects would have needed maintenance: one had some longitudinal joint

separation and the other had some raveling. The third project will have a PET evaluation in the summer of 2002.

The results from the PMS are shown below. For the rideability and rutting distresses, all of the warranty and control projects were performing very well to excellent. For the load associated longitudinal cracking all of the projects were performing excellently except the warranty project on C-470. This project is fair to poor. The cause of the cracking is not fully understood, but it is a combination of multiple factors including segregation during construction. This deficiency can be addressed by the need to re-evaluate the distress thresholds for segregation in the specification and by formalizing the accountability for the shift in responsibility (both the materials and constructibility aspects).

	Warranty			Control		
	Ride	Rut	Crack	Ride	Rut	Crack
Region 2	88	100	97	90	100	99
Region 6	88	100	74	88	100	98
				87	100	98
Region 4	95	100	99	91	100	96

Project Special Features:

For the five 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 (RAP). On I-70 at Eagle, there was an evaluation of a joint tape to improve performance of longitudinal joints.

The contractors on the control projects had no experimental features.

CHAPTER 12: Summary and Recommendations

Summary of Information:

- 1) The summary of the overall additional cost analysis for the 3-year pavement warranty projects as compared to the control projects is shown below:

Item	Cost Differential per Project
Initial Bid (based on 6 projects)	Negligible
Maintenance (based on 3 projects)	Negligible
Pavement Evaluation Team	\$ 5,400
Weigh-In-Motion Station	\$ 80,000
Total	\$ 85,400

Based on the information from the 6 warranty projects that was available at this time, the overall additional cost of a warranty project with a 3-year term was estimated to be approximately \$ 85,400. The approximate cost of a warranty project was \$3 million. The additional cost is approximately 3% of the overall project cost.

It should be noted that \$80,000 of the additional \$85,400 can be directly attributed to the cost of the weigh-in-motion station.

Assuming full implementation would include about 2 projects per Region per year, there would be 12 projects per year. The total cost would equate to approximately \$1 million per year. This is predominately from the weigh-in-motion stations.

- 2) Competition at the time of bidding for the 6 experimental warranty projects was very similar to the competition on the traditional CDOT control projects.
- 3) Performance at the end of the 3-year warranty term for the 3 experimental warranty projects was very similar to the performance on the traditional CDOT control projects. The exception was the longitudinal cracking on the C-470 project. This deficiency can be addressed by the need to re-evaluate the distress thresholds for segregation in the specification and by formalizing the accountability for the shift in responsibility (both the materials and constructibility aspects).
- 4) The contractor added experimental features on 3 of the 5 experimental warranty projects constructed. The contractors added no experimental features to the traditional CDOT control projects.

Lessons Learned and Recommendations:

- 1) The warranty specification shifts responsibility from CDOT to the contractor for some of the materials and workmanship items. There needs to be additional efforts for accountability that accompany this shift in responsibility. The following two options are proposed for future consideration:

Option 1: By specification, the additional responsibility needs to be documented by the contractor in a quality control plan prior to the project, and is to be inspected by CDOT during the project. This occurred on all of the warranty projects, but at a variety of levels (some were better than others were). There needs to be a formal audit or surveillance process in place, and training of this process needs to be provided to the Project Engineers. Although the contractors assume the responsibility for quality, CDOT has to better define the formal process to ensure that it is being taken seriously or being done at all.

OR

Option 2: The philosophy of the 3-year warranty needs to shift from a materials and workmanship philosophy to a maintenance warranty philosophy. With a maintenance philosophy, CDOT will require all of the materials properties and test for their acceptance as on a normal project. Additionally, CDOT will ask for a limited 3-year warranty.

- 2) The distress thresholds to identify the impact of segregation on performance need to be re-evaluated. On one of the projects the distress from segregation manifested in the form of longitudinal cracks that were located in or near the wheel path. These distresses were not included as a warrantable item by specification.
- 3) Triggers for the distress thresholds should rely on the use of the Pavement Management System (PMS) data. These results could trigger a PET evaluation, if one is needed. As more warranty projects come about, there are not enough resources to perform all the PET evaluations. A tie to the PMS data could lessen that concern.
- 4) The requirement of the WIM should be re-evaluated. In this time of unprecedented growth, none of the traffic projections were exceeded for the 3-year term. Although a legitimate concern by industry, it should be re-evaluated. It may only be needed on a few projects statewide, if any at all. It should be noted that up to \$80,000 of the additional \$85,400 could be eliminated based on this re-evaluation.

The requirement for a WIM should also be re-evaluated for the long-term warranty projects, but it will likely still be needed.

- 5) For purposes of the Cost Benefit Evaluation Committee, the evaluation of the performance of these pavements should not end at the end of the warranty term.

Evaluation should continue beyond that. It should include evaluations at and near the end of the design life of these pavements. That comparison will be more valuable at assessing the performance benefits of warranties than the earlier pavement evaluations.

CHAPTER 13: Future Vision / Direction

Continuation. There was limited data available from the awarded 6 warranty projects that included 3 projects whose warranty terms had expired. There was no appreciable difference in competition or performance of the warranty projects when compared to the control projects. The exception was the longitudinal cracking on the C-470 project. In order to ensure improved performance and quality on future projects, it is imperative that the lessons learned from these experimental projects be implemented. These lessons include Recommendation #1 (accountability for the shift in responsibility) and Recommendation #2 (adding segregation distress thresholds to the specification) as stated in the Summary and Recommendations Chapter.

Although there was an appreciable cost differential, \$85,400 or approximately 3% of the overall project cost, \$80,000 of that was for the weigh-in-motion station. Recommendation #3 (evaluate use of Pavement Management System data to trigger evaluations) and Recommendation #4 (re-evaluate the weigh-in-motion requirement) could address these concerns.

There was a shift in risk and responsibility as a result of the warranty projects, but at this time there was no tangible benefit identified. At this time there was no strong cost-benefit evidence to suggest that either continuation or stoppage of the 3-year warranty program will be beneficial to CDOT.

If there continues to be a move in the direction of warranties, the guidance from the CBEC would be to monitor several key indicators.

- *Reduced Competition.* It is important to monitor the competition on future warranty projects. As there are more projects, there may be a reduction in the level of competition. The bonding requirement of a 3-year warranty places a liability on the books of a contractor and creates other accounting issues. This may prevent some contractors from bidding a warranty project. If so, the warranty philosophy will need to be revisited. At this time, the competition on warranty projects is approximately equal to the control projects.
- *Bonding Cost.* The bonding industry is volatile. At the time of this report, the initial cost of the warranty was seen as negligible. However, as the bonding industry cycles through good times and bad, the value of the short-term warranty is likely to cycle. It is recommended to track the cost of this short-term warranty and continue to monitor the cost and balance it against the benefit.
- The scope of this report is for the 3-year materials and workmanship warranties on HBP. It should **not** be assumed that the conclusions in this report apply equally to a 5-year or a 10-year term warranty. It is recommended that additional analyses such as this one be performed for 5 and 10-year warranties.

Quality. It appears the quality was acceptable, but it may be more of a result of the QC/QA specification that was put in place approximately 10 years ago rather than the warranty specification. Contractors that had responded to the QC/QA specification were those that were awarded these warranty projects. It was believed that if this warranty specification were put in place 10 years ago that we would not have seen the success we are currently seeing.

Acknowledgements

The Cost Benefit Evaluation Committee (CBEC) would like to thank the contributions of Gerry Huber of Heritage Research for the assistance with the development of the Warranty Philosophy section in Chapter 1. Also, the CBEC would like to thank the contributions of the Pavement Evaluation Team of Hal Toland (CDOT), Darrel Dinges (CDOT), Tom Rolland (Consultant), and Denis Donnelly (CAPA) for providing the performance information. Stephen Henry (CDOT) compiled the pavement management system performance information.

Appendix A: Senate Bill 97-128

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.

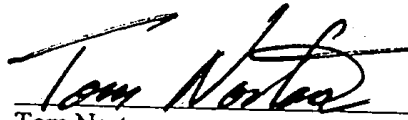
(c) WHEN A PROVISION HAS BEEN MADE FOR THE NECESSARY FUNDS, INCLUDING ANY FEDERAL FUNDS, FOR ANY QUALIFIED HOT BITUMINOUS PAVEMENT PROJECT AND WHEN THE PROJECT HAS BEEN APPROVED BY THE PROPER FEDERAL AUTHORITIES, THE COMMISSION MAY PROCEED TO REQUIRE A WARRANTY FOR A QUALIFIED HOT BITUMINOUS PAVEMENT 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).

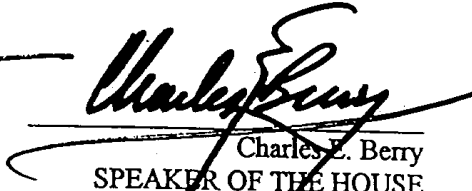
(e) ALL PAVING PROJECTS CONSTRUCTED PURSUANT TO THIS SUBSECTION (16) SHALL BE SUBJECT TO A COST-BENEFIT EVALUATION BY A COMMITTEE SELECTED BY THE COMMISSION. SUCH COMMITTEE SHALL CONSIST OF TWO REPRESENTATIVES FROM THE STATE DEPARTMENT OF TRANSPORTATION, TWO INDIVIDUALS FROM THE ASPHALT PAVING CONSTRUCTION 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

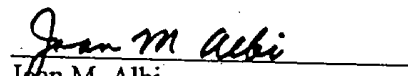
constitution; except that, if a referendum petition is filed against this act or an item, section, or part of this act within such period, then the act, item, section, or part, if approved by the people, shall take effect on the date of the official declaration of the vote thereon by proclamation of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



Tom Norton
PRESIDENT OF
THE SENATE



Charles E. Berry
SPEAKER OF THE HOUSE
OF REPRESENTATIVES

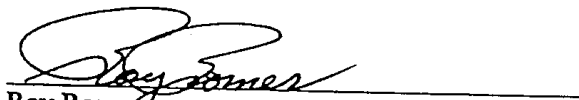


Joan M. Albi
SECRETARY OF
THE SENATE



Judith M. Rodriguez
CHIEF CLERK OF THE HOUSE
OF REPRESENTATIVES

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



Roy Romo
GOVERNOR OF THE STATE OF COLORADO

Appendix B: Pavement Warranty Provisions - CDOT's Future Direction

MEMORANDUM

DEPARTMENT OF TRANSPORTATION
Design and Construction Branch
Materials and Geotechnical Section
4340 East Louisiana Avenue
Denver, Colorado 80246
(303) 757-9449



Date: November 4, 1999

To: Regional Transportation Directors

From: 
John Unbewust
Deputy Chief Engineer

Subject: Pavement Warranty Strategic Direction

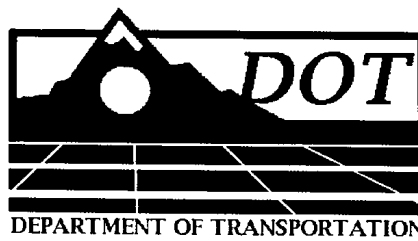
Attached for your review is a document entitled "Pavement Warranty Provisions: CDOT's Future Direction". This document, as signed, serves as the strategic direction the Department will pursue with regard to pavement warranties. Please note, although a final future implementation schedule has not been defined for short-term materials and workmanship as of the date of this memorandum, the Department will be pursuing additional warranty projects for the 2001 construction season. Please keep this in mind when developing your projects for the upcoming construction seasons.

If there are any questions regarding the strategic or the status of the long or short-term warranty specification efforts, please contact Tim Aschenbrener at (303) 757-9199.

Attachment

Cc: Region Program Engineers
Steve Horton
Tim Aschenbrener
Richard Zamora

Pavement Warranty Provisions: CDOT's Future Direction



Signed: *John Unbewust* 11-4-99
John Unbewust Date
Deputy Chief Engineer

Signed: *William Reisbeck* 11/5/99
William Reisbeck Date
Chief Engineer

Author: Richard A. Zamora, P.E.
November 4, 1999

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PAVEMENT WARRANTIES

ISSUE:

The Colorado Department of Transportation has made several attempts to implement various pavement warranty specifications, with limited success. In order to satisfy political and public demand for better performing pavements and encourage Contractors to adopt effective quality control measures, the Department is committed to pursuing pavement warranty specifications for future projects. The purpose of this paper is to outline the strategic direction for implementation of pavement warranty specifications in Colorado.

BACKGROUND:

CDOT began an effort to implement pavement warranties approximately three years ago. The original effort began as a five-year asphalt pavement warranty. State legislation was passed on May 21, 1997 requiring the Department to develop a pilot three-year asphalt pavement warranty for use on three front range projects. As a result of the legislation the five-year effort was converted to a three-year specification. The pilot projects were bid during 1997 and 1998, and constructed during the 1998 construction season.

Additionally, Region 1 advertised a five-year asphalt pavement warranty project in January, 1999. Unfortunately there was only one bidder on the project, and the bid was substantially over the Engineer's estimate. The warranty provision was removed and the project re-advertised. It has been expressed by industry that the project, as advertised, was not the most appropriate project for a five-year warranty provision because of the method selected for rehabilitation. Additionally, there were complaints about the lack of communication between CDOT and industry prior to attempting this effort.

During the Spring of 1999, Region 4, in conjunction with Staff, developed a ten year asphalt warranty specification for use on Design/Build portions of a project on SH 14. There was also extensive contractor involvement during the development process. The project was advertised in June and opened in July. Three bids were received. Low bid on the warranted project was \$8,996,047 which was 40% over the engineer's estimate of \$6,373,882. The project was re-advertised as a non warranted project and the low bid was \$4,858,483 which was over the engineer's estimate of \$4,584,728 by 6% .

In order to satisfy public demand for better performing pavements and encourage Contractors to adopt effective quality control measures, the Department is committed to pursuing future pavement warranties. Because of past problems with awarding projects with various warranty provisions, the Department formed a task force to develop a strategic direction for pavement warranties in Colorado and document the strategic direction in the form of a position paper signed by the Chief Engineer.

FUTURE STRATEGIC DIRECTION OF PAVEMENT WARRANTIES:

Development Methodology:

Members of the task force to develop the Pavement Warranty Position Paper were as follows:

Steve Horton	Design and Construction Engineer
Tim Aschenbrener	Materials and Geotechnical Section
Bernard Paiz	Design and Construction Section
John Ward	Contract Services Section
Robert LaForce	Region 1 Materials
Gary DeWitt	Region 4 Materials
Rick Chapman	Region 4 Materials
George Rowe	Region 4 Evans Residency
Bernie Kuta	FHWA
Richard Zamora	Materials and Geotechnical Section

The task force identified important stakeholders including the CDOT's executive management, the asphalt paving industry and the concrete paving industry. Meetings were held with each stakeholder to discuss their views on perceived problems with previous CDOT warranty efforts, as well as opinions regarding the direction CDOT should pursue with regard to pavement warranties. During meetings with both industry groups, some common concerns were presented. Many of the issues were financial in nature and related more to long term performance warranties. The issues included, but were not limited to, limiting contractor risk for hyper-inflation, availability of and impact on contractor bonding capacity, tax liability issues and ensuring contractors would not be held liable for items outside their control. Proper project scoping, regardless of warranty term, was also raised as a major concern. Additionally there were some concerns with the performance criteria specified. Another common theme discussed was that the cost-effectiveness of pavement warranties needs to be evaluated.

Recommendations for Strategic Direction:

Considering the input of the identified stakeholders, the two tiered approach listed in Table 1 is recommended. Table 1 depicts an approach for asphalt pavement warranties, but a similar table can be developed for use on Portland Cement Concrete Pavement (PCCP) projects. Under the conceptual approach, CDOT will quickly pursue development of short-term materials and workmanship pavement warranty specifications for both Hot Bituminous Pavement (HBP) and PCCP.

Table 1. Summary of Two -Tiered Asphalt Pavement Warranty Approach**

	Short-term Warranty Materials and Workmanship			Long-term Warranty Performance Based	
Warranty Life	3 years for 10 year Design Life 5 years for 20 year Design Life			15 years for 20 year Design Life (or greater)	
Application	All Projects : Total ESAL's > 3 x 10 ⁶ (including 2" overlays)			New/Major Rehabilitation/Reconstruction (may include D/B or Alternate Bid)	
Warranty Cost	\$			\$\$\$\$\$	
Specification Availability	November 5, 1999			October 1, 2000 (±)	
Specification Implementation	1 project per Region, 2000 Construction Season			1 pilot project in 2001 Construction Season	
Typical Projects Available (% Asphalt Program)	2" Overlay (No Design)	Rehab. 10 year Designs	Rehab. 20 year Designs	Minimal (1-3 per year)	
	25 %	45%	24%	6%	
Risk Allocation	CDOT		Contractor	CDOT	Contractor
	Rehab. Strategy		Workmanship (segregation, joints)	ESAL's – Growth Hyper-inflation	Workmanship
	Structural Design		Materials mix design and production (Must pass Hamburg)		Performance
	ESAL's - Growth		Performance during Warranty (Ravel and rut if in new pavement.)		Rehab Strategy
	Performance (crack, rut due to existing condition)				Structural Thickness
	Min. Binder Requirements			Materials Mix Design and production.	
	Pavement Type				Pavement Type

****Table may change based upon further input from industry**

Short-term Materials and Workmanship Warranties: As a part of the short-term specification development effort for both pavement types, the following key items need to be addressed:

- Risk Allocation
- Performance Criteria
- Project Selection Guidelines
- Project Scoping Recommendations
- Evaluation of Cost Effectiveness
- Warranty Term
- Implementation Plan
- Plan for Communicating with the Regions and Industry

Long-term Pavement Performance Warranties: Long-term pavement performance warranties should be pursued, but viewed as a longer-term goal than the materials and workmanship specifications. It is recommended to perform an investigation to determine the feasibility of implementing a cost-effective specification. As part of this investigation, the following items need to be addressed and documented:

- What is the objective?
- Can this be done?
- How can this be funded?
- What will it cost?
- Will it be cost-effective?
- Considerations for taxes, inflation, etc.
- How do we ensure competition from both contractors and warranty providers?

If long-term performance warranties are determined to be feasible, the bullets outlined under the short-term warranty heading above need to be addressed during the long-term warranty specification development.

Implementation Schedule:

Short-term Materials and Workmanship Warranties: Task forces, consisting of CDOT and industry members, should be formed immediately to develop short term materials and workmanship warranties for both HBP and PCCP warranty specifications. Performance criteria, project selection guidelines and project scoping recommendations for both the HBP and PCCP specifications should be fully developed by November 5, 1999. The HBP and PCCP task forces should also develop an evaluation plan to determine cost-effectiveness of the short-term pavement warranty provisions.

For HBP, the resulting specification and guidelines should be used on at least one project per Region to be constructed during the 2000 construction season.

The PCCP specification and guidelines should be used on at least one pilot project statewide to be advertised during 2000.

Long-term Pavement Performance Warranties: A task force consisting of CDOT, both the HBP and PCCP industries, and the surety/insurance industry should be formed to determine the feasibility of implementing a long-term pavement performance warranty provision. CDOT membership should include engineers and at least one financial specialist. The feasibility study should be completed and the findings documented by February 28, 2000. If long term warranties are determined to be feasible, task forces should be formed to develop specifications. Specifications should be developed by October 1, 2000 and implemented on at least one pilot project to be advertised for the 2001 construction season. A plan to evaluate cost-effectiveness should also be developed. These specifications should be compatible with both the Design/Build and Alternate Bid scenarios.

Appendix C: Project Selection Guidelines and Implementation and Evaluation Plan

HBP Warranty Project Selection Guidelines

No Warranty (potential 1 year Materials and Workmanship Warranty)	3-year Warranty	5-year Warranty
Functional overlay	≥ 10 year structural design	≥20 year structural design
Do not adequately address distress.	Adequately address existing distress	Adequately address existing distress.
Projects < 20,000 tons HBP	Projects ≥ 20,000 tons HBP	Projects ≥ 20,000 tons HBP
Remote location/Unknown Sources	Primarily paving projects	Primarily paving projects
	Traffic Verifiable (WIM or other)	Traffic Verifiable (WIM or other)
	Pre-ad constructibility review (Suggested topics include, but are not limited to inclusion of intersections, overrun considerations, night-time paving, patching quantities, and how traffic will be verified)	Pre-ad constructibility review (Suggested topics include, but are not limited to inclusion of intersections, overrun considerations, night-time paving, patching quantities, and how traffic will be verified)

HBP Short-term Materials and Workmanship Implementation and Evaluation Plan

Purpose: Develop a program consisting of a limited number of projects and an evaluation plan to determine if HBP short-term materials and workmanship specifications improve the quality of HBP pavements in a cost-effective manner.

Proposed 6-year Implementation Plan:

Year	# of Projects	Region
1998	3	(R2, R4, R6)
1999	0	NA
2000	2	(R2,R3)
2001	Minimum of 3	Statewide
2002	Minimum of 3	Statewide
2003	Minimum of 3	Statewide

- Minimum of 2 projects per Region over 6 years
- Maximum of 4 projects per Region over 6 years
- Annual evaluation reports to be developed.
- Final evaluation completed following the 2003 season.
- Decision on further implementation to be made following final evaluation.

Evaluation Criteria:

1. Performance (comparison with similar projects)
2. Adequacy of project selection guidelines.
3. Adequacy of specification
4. Costs (initial cost, life cycle cost, maintenance costs)
5. Level of competition (number of bidders, spread in bids)

Appendix D: 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,

A handwritten signature in black ink, appearing to read "James Daves". The signature is fluid and cursive, with a large initial "J" and a distinct "D".

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 E: HBP Warranty Specification Used in 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.

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REVISION OF SECTION 403
WARRANTED HOT BITUMINOUS PAVEMENT

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 My 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.

REVISION OF SECTION 403
WARRANTED HOT BITUMINOUS PAVEMENT

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 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.

REVISION OF SECT10N 403
WARRANTED HOT BITUMINOUS PAVEMENT

- (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 any segment outside the survey segments is 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	$0.25 \times D$
12 months	$0.50 \times D$
18 months	$0.75 \times D$
24 months	D
30 months	$1.25 \times D$
36 months (full term)	$1.50 \times D$

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-

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 REVISION OF SECTION 403
 WARRANTED HOT BITUMINOUS PAVEMENT

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	< 6 mm wide	Seal cracks with hot poured joint and crack sealant materials that meet the requirements of ASTM D 3405.
Moderate	< 19 mm wide < 6 mm wide with spalling or random cracking	
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.

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REVISION OF SECTION 403
WARRANTED HOT BITUMINOUS PAVEMENT

- (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.
- (9) 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)	Metric 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 F: HBP Warranty Specification Used in 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.

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REVISION OF SECTION 106
QUALITY CONTROL FOR
WARRANTED HOT BITUMINOUS PAVEMENT

- (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.

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.

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.

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. *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). 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)

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	
<u>Hot Bituminous Pavement ___** Year Warranty</u>		<u>Lump Sum</u>

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 G: Existing Pavement Structure and Aggregates Used in the Warranted HBP

Region	Project Category	Project Number	Project Name	Subaccount No.	Pavement Structure Materials Before Overlay	Thickness Before Overlay
2	Warranty	IM 0252-312	I-25, Fountain-South	12116	HBP ABC	6-1/2 inches 12 inches
2	Non-warranty	IM 0251-154	I-25, North of Pueblo	12528	HBP ABC	9-1/4 inches 12 inches
6	Warranty	NHS 4701-085	C 470, Santa Fe to Wadsworth	11595	HBP ABC	6.5 inches 17 inches
6	Non-warranty	IM 0253-144	I-25, 84th to 120th Ave.	11593R	HBP	5 to 9 inches
6	Non-warranty	IM 2254-056	I-225, I-25 Interchange to Parker Road	11594	HBP	11 inches
4	Warranty	C 0361-157	US 36 E&W of Superior Interchange	11982	HBP PCCP Sand Cushion "ballast" material Soil Types A-6 & A-7	0 to 3 inches 8 inches 1 inch 6 inches
4	Non-warranty	C 0761-170	West of Fort Morgan	11979	PCCP (Good Condition) Emulsified Asphalt Treated Base Soil Types A-1,A-2,A-3 &A-4	8 inches 4 inches
2	Warranty	IM 0251-157	Resurfacing, I-25 North	13048	HBP ABC	10 inches 14 inches
2	Non-warranty	IM 0251-154	I-25, North of Pueblo	12528	HBP ABC	9-1/4 inches 12 inches
3	Warranty	IM 0702-222	Eagle-East	12731	HBP ABC	8.5 inches 8 inches
3	Non-Warranty	STA 0821-057	SH 82, N. of Carbondale	13092	HBP ABC	6.5 inches 6 inches

Region	Project Category	Project Number	Project Name	Subaccount Number	Pit Name	Aggregate Component
2	Warranty	IM 0252-312	I-25, Fountain-South	12116	Penrose/Fountain Pit	
2	Non-warranty	IM 0251-154	I-25, North of Pueblo	12528	Two Rivers Pit, E. of Pueblo	
6	Warranty	NHS 4701-085	C 470, Santa Fe to Wadsworth	11595	Lafarge / Kiewit Western	31% 1" #57 Lafarge Quarry I 10% 1/2" Kiewit Western Co. 48% -3/8" Crystal Fines 10% -#4 Concrete Sand
6	Non-warranty	IM 0253-144	I-25, 84th to 120th Ave.	11593R	Frei #6 & #8/Brannan Pit #29	
6	Non-warranty	IM 2254-056	I-25 Interchange to Parker Road	11594	Cooley/Kiewit Western Co.	
4	Warranty	C 0361-157	US 36 E&W of Superior Interchange	11982	Asphalt Paving Co./Ralston	20% 3/4" Ralston Quarry Roc 8% 1/2" Ralston Quarry Roc 45% Ralston Quarry Fines 16% Agg. Inc. Sand 10% Coors Fines
4	Non-warranty	C 0761-170	West of Fort Morgan	11979	25th Ave/Spec Agg/Dorn	
2	Warranty	IM 0251-157	Resurfacing, I-25 North	13048	Fountain Pit/Menzer Quarry	20% Fountain 1/2" Rock 16% Menzer Granite Sand 17% Washed Granite Sand 26% Menzer 1" Rock 20% RAP
2	Non-warranty	IM 0251-154	I-25, North of Pueblo	12528	Two Rivers Pit, E. of Pueblo	
3	Warranty	IM 0702-222	Eagle-East	12731	Eagle Pit	
3	Non-warranty	STA 0821-057	SH 82, N. of Carbondale	13092	KWC/Roaring Fork Aggregate's Powers Pit Elam Construction Inc.'s Pit(Carbondale) & Vagneur Pit (near Aspen)	

Appendix H: Summaries of Survey Responses

Survey for the Cost Benefit Evaluation Committee
Summary of Responses
Contractor's Personnel
04-17-2001

- 1) Did this project meet the project selection guidelines? Was it an appropriate project for a warranty? Why or Why not?

Four out of five responses stated that the project met the project selection guidelines. Two of the four affirmative responses qualified their replies. One response stated that the pre-ad constructibility review was not performed but the suggested topics were discussed during a pre-bid walkthrough. Another response indicated that it was not an appropriate project for a warranty because the project mainly involved milling and overlay that could not fix underlying problems. One response did not provide any answer.

- 2) Was the specification adequate? What are areas of the specification that were successful? What are areas of the specification that need improvement?
- Three out of five responses stated that the specification was adequate. Two responses did not have any answer. One response stated that the specification adequately addressed cracking and took away the risk from thermal and reflective cracking. Another response stated that one area of the specification that was successful was not addressing either the longitudinal or transverse cracking if proper binder was used. Improvements could include the specification of the grade of asphalt and the requirement of a minimum lift thickness of 2-1/2" for grading S to make the step taper joint more workable.

- 3) What worked and didn't work on this warranty project? Please explain.

Two out of five responses had no answers. One response stated that use of RAP worked. One response stated that the project gave the contractor a heightened sense of risk because the project would be evaluated differently and over a longer period of time compared to a standard voids acceptance project. Another response stated that the CDOT Project Engineers were very cooperative and responsive to the contractor's proposal to make changes that would improve the final product.

- 4) Where there any special features on the project since it was a warranty project? Examples: test sections, control of RAP, efforts for longitudinal joint performance, etc.

One response stated none. One response stated a TLA section. One response stated using RAP and testing it once a day during crushing. The same respondent tried using a step-taper joint maker with limited success. One response stated that the contractor performed a lot more aggregate production and hot mix quality control on the project. The same respondent stated experimenting with several new products and techniques to insure good longitudinal joints on the project. One response indicated that the contractor knew that there was a greater risk if the best known production and paving practices were not followed so the contractor stayed away from doing special features.

5) I need a copy of the Quality Control Plan. Can you send it to me?

Copies of the QCP were already available from the survey of CDOT's Construction personnel.

6) How was the QCP used?

Two out of five responses had no answers. One contractor used it as a guideline and another contractor used it to ensure that all phases of the project were on the same page. One contractor used it to measure in-place voids analysis.

7) How did the contractor assure that the QCP was followed? How did the contractor address deviations in quality as identified by the QCP?

One response stated that the QC Manager performed a daily audit of the production and found no deviation. Another contractor stated using Western Colorado Testing in the same manner as any voids acceptance job. One contractor simply stated that plans and specifications were followed similar to a non-warranty project but the adjustments were made much quicker. Another contractor stated that the QCP gave the QC Manager the authority to address any deviation in the plan.

8) How did CDOT assure that the QCP was followed?

One response had no reply. One respondent indicated "unknown" in its answer. The other three responses stated the CDOT personnel monitored the implementation of the QCP.

9) How could you quantify the level of quality activities and quality testing done on the warranty project compared to standard projects? More, less, much more, much less? Please explain and provide examples.

Three contractors stated that they did not do additional testing beyond what they normally did with the standard CDOT project. Two contractors did more quality testing than usual. The amount of volumetric testing was slightly higher than a voids acceptance project. The testing of aggregate and hot mix production was done at much frequent intervals. The durability of the aggregate was closely monitored than usual.

**Survey for the Cost Benefit Evaluation Committee
CDOT Construction Project Personnel
2-08-2001**

- 1) Did this project meet the project selection guidelines? Was it an appropriate project for a warranty? Why or Why not?

Responses:

Colorado Project No. IM 0252-312, I25, South of Fountain.

The project did not entirely meet the project selection guidelines because there was a significant amount of work that was not paving like concrete culvert box (CBC) extensions, earthwork and guardrail. Also, the traffic counts used were inaccurate and the pavement distress was not properly addressed. It was not an appropriate warranty project for a 3-year period because being a 4-inch thick overlay project, it could easily survive this warranty period. A 2-inch overlay is probably more appropriate for a 3-year warranty.

Colorado Project No. NHS 4701-085, Santa Fe Drive to Wadsworth Boulevard.

The Project Engineer was not sure if the project met the project selection guidelines. The existing distress was not initially addressed in the original plans.

Colorado Project No. C 0361-157, US 36, E & W of Superior Interchange.

Yes. This section of asphalt is directly above concrete. This made the section structurally sound.

Colorado Project No. IM 0251-157, I-25, North of Pueblo.

Yes, this project met the warranty project guidelines. The existing pavement was typically roto-milled ¾" throughout the project length to remove surface distress and irregularities. The project required 71,105 tons of HBP that exceeded the minimum 20,000-ton selection guideline.

Colorado Project No. IM 0702-222, I-70, East of Eagle.

No. This project did not meet the warranty selection guidelines. The project was too big (12 miles long). The Resident Engineer was instructed by the management to convert this project which was already 99 percent completed to a warranty project to meet the Region's goal for last year. The Resident Engineer revised the acceptance specification to reflect the change to a warranty project. The Project Engineer stated that a low-grade oil was used because of the short warranty period of 3 years. He said that we got what we paid for. He also thought that a longer warranty period was necessary. The oil and the design years should be specified.

- 2) Was the specification adequate? What are areas of the specification that were successful? What are areas of the specification that need improvement?

Responses:

Colorado Project No. IM 0252-312, I25, South of Fountain.

The Project Engineer was uncertain if the specification was adequate or not because he believed that a 2-inch overlay was more appropriate for a 3-year warranty project. The typical sections on the plans required 4 inches of asphalt overlay but the specifications did not require that the overlay be placed in lifts. The Contractor could have placed one 4-inch lift and could have made a profit even if the contractor took a hit on smoothness.

The specification excluded transverse cracking if the asphalt cement met or exceeded the low temperature requirement for PG 70-34. The Contractor contended that the benefit from PG 70-34 was only on the top mat and to place it on the lower mat would be a waste. CDOT Construction personnel agreed to allow AC-20 in the lower mat and PG 70-34 in the top mat. This implied that CDOT would share in the cost of transverse crack sealing. Traffic control for all corrective work would still be the responsibility of the Contractor. The whole process would be smoother if the specification allowed the Contractor to have full control over the mix and to be responsible for everything during the warranty period. This issue on which asphalt grade to use would not have surfaced if the overlay required was only 2 inches.

The specification required a minimum thickness and allowed 5% overrun of plan quantity. The Project Engineer believed Contractors target 105% for their yield and this should be accounted for in the project budget particularly on larger projects.

It would be helpful if the specification requires the Contractors to install some type of permanent stationing to streamline the process of preparing for the inspection by the Pavement Evaluation Team (PET).

Colorado Project No. NHS 4701-085, Santa Fe Drive to Wadsworth Boulevard.

The specifications were not adequate to control the work on this project. The warranty special provisions basically deleted Section 401 of the Standard Specifications. The warranty specification only required a pavement that would last just for three years.

Colorado Project No. C 0361-157, US 36, E & W of Superior Interchange.

Yes, the specification was adequate. The criteria for a 3-year period were the successful areas in this specification. The areas of specification that needed improvement include: clarification of pavement acceptance date and traffic control responsibility for the warranty inspection activities; addressing the ability to have day closures during inspection; and addressing night inspection.

Colorado Project No. IM 0251-157, I-25, North of Pueblo.

One area of concern was the up-front level of quality during the paving process. There could be some slight segregation problem but this would not be addressed immediately because the Contractor did not want to stop the process although the Project Engineer wanted to stop the operation. The Contractor would be willing to do repair in the future but not up-front replacement or correction knowing that a review team would inspect and monitor the pavement performance anyway.

Colorado Project No. IM 0702-222, I-70, East of Eagle.

The specification was too open. The CDOT Construction personnel were worried that the specification as written would appear to satisfy a 5-year design mix or less but yield a product designed just to outlast the warranty. The specification allowed for the choice of oils but did not specify a design life. CDOT did not have a final say in the acceptability of the design mix. CDOT could comment but could not deny a specific submittal.

The Project Engineer pointed out that the specification was written assuming that the Contractor would use a certain oil to deal with reflective cracking. This assumption was wrong because the Contractor chose to use cheaper oil and crack seal material as required. It was a gamble the Contractor may win leaving CDOT with a project requiring another overlay sooner than expected.

- 3) What worked and didn't work on this warranty project? Please explain.

Responses:

Colorado Project No. IM 0252-312, I25, South of Fountain.

The Project Engineer stated it was hard to evaluate what worked on this project relative to the warranty specification. Accordingly, the Contractor was very conscious of the likelihood of similar future warranty projects being advertised by CDOT. The Contractor considered this as a pilot project with which the Contractor could evaluate the performance of the company in building a warranty project. The Project Engineer thought the Contractor was very proactive in ensuring good quality control rather than waiting for the state inspector or tester to report that there was a problem. The Project Engineer could not conclude whether or not CDOT had received a better final product compared with using the non-warranty project specification.

Colorado Project No. NHS 4701-085, Santa Fe Drive to Wadsworth Boulevard.

The physical properties and testing specifications worked out alright. The absence of 401 specifications made it difficult to control the project.

Colorado Project No. C 0361-157, US 36, E & W of Superior Interchange.

The warranty specification needed to specify the traffic control responsibility for warranty inspections and to address the ability to conduct inspection during day or night.

Colorado Project No. IM 0251-157, I-25, North of Pueblo.

The Contractor was motivated to try providing a high-quality product. The Project Engineer believed that this warranty project was a success. He believed that the longitudinal joint specification would need some clarification and the definition of what a high-quality, straight, and level joint should be clarified by the specification.

Colorado Project No. IM 0702-222, I-70, East of Eagle.

The Resident Engineer stated that we paid for what we got (cheap low bid) and handed the Contractor about \$1,000,000 in profit that the Contractor may or may not need to maintain the warranty. Through conversation with the Contractor, the CDOT Resident Engineer had determined that the Contractor had built in to the project cost a limited crack sealing project

for the 3rd year after project completion. The Contractor saved \$500,000 in cost utilizing the cheaper oil.

The CDOT Region 3 head tester commented that communication regarding changes in mix design was nil. He asked several times for documentation on oil content and gradation changes to the mix design but he never received any of them.

- 4) Were there any special features on the project since it was a warranty project? Examples: test sections, control of RAP, efforts for longitudinal joint performance, etc.

Responses:

Colorado Project No. IM 0252-312, I25, South of Fountain.

Two samples were removed from the northbound and southbound travel lanes for rut tests. The Contractor established several test sections in the southbound travel lane to evaluate various forms of crack and joint treatments. These test sections were not required by the contract. The Contractor wanted to evaluate crack and joint sealant for possible use on future warranty projects.

Colorado Project No. NHS 4701-085, Santa Fe Drive to Wadsworth Boulevard.

There were no special features on this warranty project according to the Project Engineer.

Colorado Project No. C 0361-157, US 36, E & W of Superior Interchange.

According to the Project Engineer, the longitudinal joints at the shoulder lines and the concrete and asphalt interface were not required to be warranted because of the underlying concrete. A test section for plowable raised pavement marking was added without any type of impact on the warranty.

Colorado Project No. IM 0251-157, I-25, North of Pueblo.

Yes, a WIM station was installed on the project for long-term monitoring of the traffic loads.

Colorado Project No. IM 0702-222, I-70, East of Eagle.

This project included an asphalt test section for the proposed material for use in the Glenwood Canyon paving. The project also included a test section run for the longitudinal joint in the eastbound lane near milepost 149 and involved a product that was laid on the adjacent joint before the asphalt was placed and compacted against the joint. This product was supposed to melt and help seal the joint. In addition, this project corrected a major slide area that was distressing the pavement through approximately a ½-mile section.

- 5) I need a copy of the Quality Control Plan. Can you send it to me?

Responses:

Copies of all the Quality Control Plans (QCP's) for all completed warranty projects were sent in by the Resident and Project Engineers. They are available for review from the Cost-Benefit Evaluation Committee's (CBEC) folder files.

- 6) How was the QCP used?

Responses:

Colorado Project No. IM 0252-312, I25, South of Fountain.

The Contractor utilized the company's own Quality Control Manager to oversee the implementation of the QCP. Consultants performed most of the daily project testing.

Colorado Project No. NHS 4701-085, Santa Fe Drive to Wadsworth Boulevard.

The QCP was submitted and used on this project by the Contractor's personnel.

Colorado Project No. C 0361-157, US 36, E & W of Superior Interchange.

The Contractor's personnel followed the QCP.

Colorado Project No. IM 0251-157, I-25, North of Pueblo.

As indicated in the QCP.

Colorado Project No. IM 0702-222, I-70, East of Eagle.

The QCP was submitted. However, the QC/QA program was not a project specification. Meeting the density requirements was not deemed important to the Contractor as neither incentive nor disincentive was provided to maintain quality.

- 7) How did the contractor assure that the QCP was followed? How did the contractor address deviations in quality as identified by the QCP?

Responses:

Colorado Project No. IM 0252-312, I25, South of Fountain.

The Contractor's testers charted the data as required except that they did not consistently post their test results in a timely manner. Since both Contractor's plant and field lab were on site, the communication of test results from the tester to the plant had been very efficient. The test results indicated that the Contractor was producing a consistent product. The Project Engineer did not recall any significant deviations in quality.

Colorado Project No. NHS 4701-085, Santa Fe Drive to Wadsworth Boulevard.

The final test records indicated that the asphalt produced for this project more than met the minimum requirements. On the other hand, the finished overlay had lot of open areas (segregation, rock pockets, rough longitudinal joints, etc.).

Colorado Project No. C 0361-157, US 36, E & W of Superior Interchange.

The Project Engineer did not remember how the Contractor assured that the QCP was followed. He did not recall any problems. According to him, the Contractor's personnel did not send out the mix if they thought there was a potential problem like the first production load of each night.

Colorado Project No. IM 0251-157, I-25, North of Pueblo.

The Contractor engaged in an ongoing communication with the Project Engineer by providing daily test results of the QC/QA process.

Colorado Project No. IM 0702-222, I-70, East of Eagle.

The CDOT Region 3 head tester stated that test results were entered into The Asphalt98 and Voids Acceptance (QPM) programs. Results were sent to Contractor's Quality Manager several times a week. The testers

on the project kept the Hot Mix Plant operator and Project Superintendents apprised of the test results as they became available.

- 8) How did CDOT assure that the QCP was followed?

Responses:

Colorado Project No. IM 0252-312, I25, South of Fountain.

CDOT personnel assured that the QCP was followed by periodic checking of the Contractor's paperwork. No formal assurance testing was performed, although CDOT personnel did check a few densities.

Colorado Project No. NHS 4701-085, Santa Fe Drive to Wadsworth Boulevard.

The specification did not allow CDOT to be involved with the enforcement of the QCP.

Colorado Project No. C 0361-157, US 36, E & W of Superior Interchange.

CDOT assured that the QCP was followed by monitoring the Contractor's quality control activities.

Colorado Project No. IM 0251-157, I-25, North of Pueblo.

CDOT personnel assured that the QCP was followed by having daily communication with the Contractor's personnel and requiring them to submit the materials required in the QCP. CDOT Regional Lab performed QA testing at the 10,000-ton frequency. Binder samples were also obtained and sent to CDOT Central Lab for testing.

Colorado Project No. IM 0702-222, I-70, East of Eagle.

The CDOT Region 3 Head Tester stated that he received copies of the Asphalt 98 and Voids Acceptance (QPM) printouts whenever requested. CDOT did check testing with the technicians on the project. CDOT's personnel also received copies of field test results as requested.

- 9) How could you quantify the level of quality activities and quality testing done on the warranty project compared to standard projects? More, less, much more, much less? Please explain and provide examples.

Responses:

Colorado Project No. IM 0252-312, I25, South of Fountain.

It appeared that there were more tests conducted by the Contractor on this warranty project compared to a standard CDOT overlay project. It was hard to say whether this would translate to more control of the final product. Since the test results were not posted promptly after completion, CDOT could not ascertain if the tests were run on time. If run on a timely fashion, these test results could aid the Contractor to control the product had there been any significant deviations.

The Project Engineer also thought that it would be useful to have assurance testing done by the Region's lab. He also stated that although the Contractor would be responsible for the material and the final product during the warranty period, it would be beneficial for CDOT to obtain its own data to evaluate the roadway over the long term.

Colorado Project No. NHS 4701-085, Santa Fe Drive to Wadsworth Boulevard.

There was a considerable amount of testing done on this project by the Contractor. The number of tests was a lot more than CDOT's standard project. CDOT required a lot less number of tests.

Colorado Project No. C 0361-157, US 36, E & W of Superior Interchange.

The QA testing was taken more seriously. The plant ran all mixes "live" and none from the silo. The Contractor did not pave if roadway was wet or if there was even a small potential for rain. The Contractor cleaned and tacked the existing pavement in a manner much better than a normal project without being told. The Contractor patched areas of delamination ahead of the paver at his expense. The Contractor did not empty the hopper onto the roadway and did pave a little thicker at his own cost. The Contractor, however, overrun the original quantity and CDOT paid for the excess quantity placed.

Colorado Project No. IM 0251-157, I-25, North of Pueblo.

CDOT performed less daily testing of the installed materials because the pavement would be the responsibility of the Contractor during the warranty period. The Project Engineer believed CDOT's major role in warranty project like this was to document and perform general QA checks. CDOT still provided a full-time inspector to help oversee and monitor the process.

The Contractor performed almost all the QC activities and did not rely on CDOT for information as the Contractor sometimes had the tendency to do. The Contractor had to closely monitor the density, segregation, thickness, oil content, gradation, surface preparation, and smoothness to insure long-term performance of the finished product. The CDOT Construction personnel believed that warranty project provided the Contractor a sense of ownership of the final product that was built.

Colorado Project No. IM 0702-222, I-70, East of Eagle.

The Resident Engineer stated that more testing was required because he wanted to make sure that CDOT was getting what was specified. He said that letting the Contractor do all the testing and providing CDOT with certifications was like letting the fox guard the hen house. The residency ran its own test at ½ the rate of standard project. The residency's testers also took numerous representative samples that had not been tested but gathered for testing if needed.

The Project Engineer felt that CDOT could do no testing on a warranty project. The Resident Engineer could concur with this if CDOT were willing to trust the private sector. He said that there should be mandatory testing requirements built into the project, with specific requirements if failing test occurred, possibly a hefty negative incentive payment.

The Head Tester offered the following comments:

Stockpile sampling and crusher control samples were run constantly to keep gradation within specification. Voids and VMA were run daily even though they were not required by

the Contractor's QCP. CDOT ran 10k samples also. CDOT sent 10k samples to Lafarge's Lab in Denver for testing but had not received any test results yet.

The Contractor was very unresponsive to requests regarding mix design changes. However, test personnel on the job site were very responsive and candid regarding test results. The Head Tester was kept aware of nearly all the problems verbally. There really was not anything in writing regarding out-of-specs materials and the changes made to get the material back within specification.

Technician at the HMA plant stayed in contact with the tester in the field running densities to let the technician know about the variations in the mix and how they would affect the rolling operations at the job site. Since this was not a QC/QA controlled project, consistency in density's test results was not as critical. Inconsistency in test results could cause a large negative pay factor.

The Project Engineer stated that the Contractor did more testing than would be expected on a standard project. He noted that the Contractor did voids acceptance testing as well as QC/QA testing. He also felt that CDOT testing could be eliminated on a warranty project.

The Resident Engineer offered the following comments:

While CDOT got some cheap bids, this project looked like a great success on paper. He was concerned that CDOT was jumping ahead in a final decision to go this way not knowing the final results. His opinion was to wait a few years and get the final results before going whole hog down this road.

The Resident Engineer felt CDOT could have gotten a better project and saved a million or so in the process by using proven mix designs and tightening up on the quality control. That is, possibly offer heftier incentive payment for great work, along with heftier disincentive payment for lousy work. He stated that CDOT should run itself as a business that rewards good work and rejects lousy work. In the real world, lousy contractors do not get the work even if they are the low bidders. Developers often choose the second low or another bidder due to reputation of good work. CDOT does not have a real choice and must accept low bid. He suggested that with stiffer disincentives and greater rewards, CDOT could weed out the bad apples and get better pavements. He said, either way, CDOT would be paying more for what it is getting now.