

**DISPUTE REVIEW BOARD REPORT
AND RECOMMENDATION
I-25 FRONTAGE ROAD
DOUGLAS COUNTY, CO
CDOT PROJECT NO. C 0252-390**

DISPUTE CONCERNING PCCP DOWEL BAR PLACEMET

Hearing Date: February 17, 2010

Hearing Location: CDOT Region 1
7328 South Revere Parkway, Suite 204A
Centennial, CO

Hearing Attendees: Carrie DeJacomio – CDOT – Region 1 Program Engineer
Roman Jauregui – CDOT – Resident Engineer
Bill Schiebel – CDOT Region Materials Engineer
Jay Goldbaum – CDOT – Pavement Design Program Manager
Brian Kelly – CDOT – Construction Inspector
Scott Rees – CDOT – Area Engineer
Skip Spear – CDOL – Assistant Attorney General (Observer)
Daryl Miller – AECOM – Construction Inspector
Rick Lawrence – Lawrence Construction Co. – President
Marc Bliven – Lawrence Construction Co. – Project Manager
Ralph Bell – Castle Rock Construction Co. – COO
Gary Ungerman - Castle Rock Construction Co. – General Supt.
Greg Nejexchleb - Castle Rock Construction Co. – Sponsor
Paul Okamoto – CTL Group – Consultant for CRCC

Background:

Lawrence Construction Co. was awarded a contract by CDOT for the widening of I-25 to four lanes in each direction and the construction of a new Frontage Road, approximately 2.6 miles long, on the east side of I-25 from Castle Pines Parkway to the Ridge Gate Project on the north end. The Frontage Road will be owned by Douglas County. Castle Rock Construction Co. was a subcontractor to Lawrence and performed the Portland Cement Concrete Paving (PCCP) work. The Notice to Proceed was issued on October 29, 2008 and the concrete paving was completed on July 2, 2009.

Joint Statement of Dispute:

CDOT and Lawrence Construction Company/Castle Rock Construction Company (Contractor) do not agree on the price reduction for Portland cement concrete pavement (PCCP) installed with dowel bars that are misaligned significantly beyond the specification tolerances, or installed without dowel bars. CDOT has assessed the dowel bar installation using a statistically defensible frequency to attain a 95% confidence in the data. Installation data were then modeled using MEPDG

pavement modeling software to assess the impacts to long term performance of the PCCP. Contractor's desire is that the DRB determine what responsibility each party held with regard to the dowel placement. CDOT's desire is that the DRB consider the data and approach used by each party to calculate the respective price reductions. Both parties desire a ruling on a price reduction with consideration for the PCCP maintenance anticipated as a result of the misaligned or missing dowel bars.

Pre-hearing Submittal:

Both parties provided the DRB with Pre-hearing Submittals per Spec. Section 105.22(e), the Lists of Contents of which are included in Attachment 1. Both parties provided the DRB with their lists of attendees.

Contractor's Presentation on the Quality Control Plan:

The Contractor gave a background on its use of Guntert & Zimmerman pavers with Dowel Bar Inserters (DBI) starting in 1998 and had found the machines reliable for dowel bar placement. Two years ago they bought a Model A250 and sent six people to the factory for training. This Project was the second one on which they used the new machine. The DBI is now back at the factory due to problems. The DBI uses a computer controlled marking system to show dowel bar placement but the locations were wrong or non-existent. The manufacturer has stated that the dowel bars could rotate with the vibration used for placement.

The Contractor provided the DRB with a copy of the Quality Control Plan. The Q C Plan states – *Dowel Bar Placement: Tests will be made on six random transverse joints in each 2500 lineal feet of pavement placed in accordance with the special provisions.* The Quality Assurance was to be performed by CDOT by witnessing the tests performed by the testing Consultant. Dowel bar locations were checked using a cover meter which is accurate for dowel bar depth but there are questions on the accuracy in determining the ends of the dowel bars. The Contractor stated the QC/QA program, did not work. Although the PCCP placement was complete on July 2, 2009, the first objections that the Contractor received from CDOT were on July 20. The Contractor believes there should be a shared responsibility for the placement problem since no one raised a flag.

CDOT's Presentation on the Quality Control Plan:

CDOT went over the dowel bar tolerances and the testing requirements. They stated the Contractor was responsible for Quality Control and that CDOT only witnessed the QC testing. CDOT referred to Spec. Section 105.15 which states the testing and inspection by CDOT is for CDOT's convenience. They also covered Spec. Section 105.16 concerning unacceptable work and the removal of such and Spec. Section 107.21 concerning latent defects. CDOT stated that the Contractor was ultimately responsible for the work and that the CRCC knew of the concerns of the DBI performance, that CDOT's actions were irrelevant under the Contract, and under the cited Specs. the risk was on the Contractor.

Questions by the DRB on the Quality Control Plan:

What was the daily documentation?

The QC notebook has the information but it was not dated.

Who did the testing?

The tester worked for CRCC and tested for concrete depth, strength and fine aggregates. The northbound (NB) joint testing was done on June 30, 2009 and the southbound (SB) on July 22, 2009.

Contractor's Presentation on the PCCP dowel Bar Placement:

The Contractor said that the PCCP paving had two 12 foot lanes and shoulders. Some dowels were placed using baskets before the pour and the DBI placed other dowels.

CDOT's Presentation on the PCCP dowel Bar Placement:

CDOT reviewed the PCCP placement and the cover meter testing. The NB paving was completed on June 22, 2009 and the dowel bar cover meter testing was done on June 30, 2009. Dowels were detected in the NB paving. The SB paving was completed on July 2, 2009 and the cover meter testing was done on July 22, 2009 showing that no dowels were detected in 11 of the 37 joints that were tested. Based on the cover meter test results and the documented problems with the DBI, CDOT had concerns over the missing and possibly misaligned dowel bars. CDOT then decided to use their Magnetic Imaging Technology device (MIT) to quantify the dowel bar placement problems within the Project. The MIT tested 52 SB joints on August 10, 2009 and found 4 joints with no dowels and 40 joints with dowels out of tolerance. On August 13, 2009 CDOT used the MIT device to perform randomly selected joints from each day's placements for both NB and SB paving. One hundred seventy-five joints were tested and showed that on a single day's paving on NB there were 300 feet of paving with no dowel bars and that 24% of the dowel bars were out of horizontal translation tolerance.

On November 3, 2009, CDOT performed additional MIT testing. They used a random sampling of all the paving. Fifty joints were tested and showed that 6% of the joints had no dowels and 100% of the joints were out of Contract tolerances. Based on this data, CDOT prepared a White Paper on their findings, Attachment 2.

Contractor's and CDOT's Rebuttal on the PCCP dowel Bar Placement:

The Contractor stated that it was hard to argue with the testing and resulting information that was done by CDOT. CRCC did remove and replace a 300 foot section at their expense and found in the removal that dowels were missing in 5 joints and that other dowel bars were installed but were in the wrong locations. They offered CDOT a 10 year Warranty but were not able to get a bond to cover the warranty

CDOT said that their assessment of the joints was based on field sampling per the Central Limit Theorem – minimum of 30 joints required and they tested 50. Their

analysis used long term performance impacts modeled on the Mechanistic-Empirical Pavement Design Guide (MEPDG) and indicated a

projected smoothness limit being exceeded in year 9 where there are no bars and at year 17 where the dowels are misaligned. The typical CDOT PCCP rehab is at 22 years and consists of ½ percent slab replacement, diamond grinding 50% of travel lanes and joint resealing.

CDOT did state that they did a retro analysis that allowed acceptance if there were 3 dowels in the wheel path.

Questions by the DRB on Dowel Bar Placement:

Why wasn't the paving just replaced?

Neither CDOT or the Contractor wanted the public to see all the paving being removed and redone and there was pressure to get the Frontage Road open.

Was the use of the MIT in the Specs.?

The Spec. does not call out the testing equipment but there are provisions for special verification. CDOT said they were satisfied with the accuracy of the MIT device and had been using it for 3 years. Without the MIT, the only way to really know dowel bar locations was to use destructive testing.

Did the cover meter results indicating no dowels raise a flag?

The cover meter was checked and there was a loose wire so the results were suspect.

What inspections were done prior to the placements?

The dowel bar baskets were looked at ahead of time.

Why were 1" dowel bars used instead of the 1¼" or 1 ½" dowel bars normally used by CDOT?

Douglas County requested the use of the 1": dowel bars.

Contractor's Presentation on Price Reductions:

The Contractor furnished a spread sheet showing their price reduction analysis and the CDOT analysis along with pricing data, Attachment 3. CRCC originally offered a \$72,000 reduction based on the cost for full pavement rehab in year 17 for all areas with misaligned joints and the costs for grinding and dowel retrofit for all panels without dowels at year 9. but the reduction did not include the CE Rate that CDOT adds to all their construction costs. The Contractor reviewed their basis for the Unit Prices that were used in their analysis. Their analysis basically used the CDOT quantities and the CRCC Unit Prices

Paul Okamoto who is with CTL Group in Chicago gave some background on himself. He has been involved with concrete pavement for 27 years and has done considerable work in Colorado, some for CDOT. CRCC asked him to review the CDOT analysis using the MIT data. He said he wanted to comment on the CDOT

analysis and the projected major rework being done in 17 years rather than the planned 22 years. He then made a presentation on his dowel bar alignment analysis using the testing that had been obtained by CDOT using the MIT, Attachment 4. He referred to the National Cooperative Highway Research Program (NCHRP) Report 637 – *Guidelines for Dowel Alignment in Concrete Pavements*. This is the same reference used by CDOT. The crux of his presentation centered on the use and selection of data and how it was then applied to the lifecycle analysis. Based on a confidence Interval of 95%, he was projecting a life of 20 to 21 years.

CDOT questioned the use of the Contractor's expert since nothing had been submitted prior to the Hearing on what the expert would present.

CDOT's Presentation on Price Reductions:

CDOT referred to Spec. Section 105.03 concerning tolerances and conformity with the Contract and the removal and replacement of unsatisfactory work at the Contractor's expense. CDOT said that retrofitting (unless all joints were tested), warranty without a performance bond, and the removal and replacement of the PCCP had been removed from consideration. Using the NCHRP 637 Guidelines, they looked at alternatives considering impacts to long term performance. They used CDOT's historical cost and pricing data along with Project location to determine their Unit Pricing.

CDOT's Proposal #2 – 16.7 pay reduction for full DBI pavement based of 5 year loss of smoothness and 6% Pay Reduction for the panels where no dowels exist – had been provided to the Contractor. The price reduction is the same one shown on the CRCC spread sheet and totals \$252,308.

Questions by the DRB on Price Reductions:

Why were the price reductions in Spec. Section 105.03 not used?

It was based on engineering judgment and the options were not attractive.

Was MOD 16 signed and what funds are currently withheld?

MOD 16 was not signed and approximately \$248,000 is being withheld.

Summation Statement by Contractor:

The Contractor said there were three areas to consider:

- CDOT should have some quality/inspection responsibility since they or their inspectors were always on the job and shouldn't wait until the end of the job if there was a problem.
- The Price Reduction spread sheet needs to be looked at – CDOT's Unit Prices are not what is being seen on bids today. Look at the CRCC Contract PCCP price of \$26.70/SY for the job vs. the prices CDOT is using for the Price Reductions.
- Paul Okamoto's presentation and points need to be considered - The CDOT factors and 95% confidence are too high.

Summation Statement by CDOT:

CDOT offered the following points:

- The Contractor knew on site that there were problems with the DBI and the new paver. CDOT let them continue with the paving.
- It should make no difference whether a cover meter or the MIT was used since there were missing or misaligned dowel bars.
- CRCC is ultimately responsible for the finished product.
- CDOT has a problem with CRCC's expert interpretation of the data.
- The Project was done under no traffic and in the future there will be more costs if the repairs are done under traffic.
- CDOT feels they have presented several equitable solutions to the Contractor.

Recess by DRB for Discussions

Reconvene:

Based on the issues raised by CDOT on the Contractor's expert, the Board offered the following to the parties:

- Allow the experts of both parties' to discuss their positions on the use of the NCHRP 637 report.
- Both Parties must agree to conduct the discussions.

The parties agreed to a phone discussion and agreed to conduct the discussions no later than March 2, 2010 and submit their agreements, if any, to the DRB.

The Hearing will be closed upon receipt by the DRB of the outcome of the discussions.

Results of Expert Discussions:

The parties held a meeting/conference call on March 1, 2010 to discuss the analyses of both parties. CDOT provided the DRB with the outcome of the meeting, Attachment 5, which included Paul Okamoto's analysis that was provided to CDOT prior to the meeting. The outcome of the meeting was confirmed by the Contractor via email. It was agreed to use 19 years in the analysis for any price reductions.

Findings:

Based on the agreement of the parties on how the pavement life should be evaluated and on what items should be considered for the Price Reduction, the DRB felt it was proper to accept these agreements and decide on what Unit Prices should be used for the Price Reduction. In arriving at the Unit Prices, the DRB reviewed the Unit Prices as presented by CDOT, the Unit Pricing information that was furnished by the Contractor for various Unit Prices from other construction bids and proposals and a review of cost data from recent CDOT bids.

The DRB feels that since the use of the DBI equipment has shown problems in the past with dowel bar placement, both parties should have been more aware of the actual dowel placement during the paving process. It also suggests that placement verification needs to be added to the Quality Control Plan. The Quality Control Plan

DISPUTE REVIEW BOARD REPORT AND RECOMMENDATION

CDOT PROJECT NO. C 0252-390

Page 7 of 21

should include specific quality control test procedures, equipment calibration, test result verification procedures, and daily testing and reporting procedures. Quality Control testing at daily start up should be implemented until satisfactory results are being achieved consistently. If satisfactory results are not achievable within 400 ft production should be stopped and corrections made.

Recommendation:

The following format is the same as the one presented to the DRB at the Hearing.

Option 4a - Remove and Replace 6% of the Panels Placed with the DBI

Remove and Replace PCCP	2,016 SY @ \$86.00/SY	\$173,376
Traffic Control	15 Days @ \$1,000/Day	15,000
Sawing and Sealing Joints	6,048 LF @ \$1.59	9,616
Diamond Grinding	2,016 SY @ \$10.00/SY	<u>20,160</u>
	Subtotal	\$218,152
	CE Cost (23.95%)	<u>52,247</u>
		\$270,399
	PWF (74.68% in year 9)	\$201,934

Option 4b – Retrofit & Diamond Grind 6% of Panels Placed with DBI

Stitch 6 bars per Joint	756 bars @ \$45/Bar	\$ 34,020
Traffic Control	15 Days @ \$1,000/Day	15,000
Sawing & Sealing Joints	6,048 LF @ \$1.59	9,616
Diamond Grinding	2,016 SY @ \$10.00/SY	<u>20,160</u>
	Subtotal	\$ 78,796
	CE Cost (23.95%)	<u>18,872</u>
		\$ 97,668
	PWF (74.68% in year 9)	\$ 72,938

DISPUTE REVIEW BOARD REPORT AND RECOMMENDATION

CDOT PROJECT NO. C 0252-390

Page 8 of 21

Option 5 – Difference in Cost of Rehabilitation at Year 19 Instead of 22

(50% of Travel Lanes – 1048 Panels)

Sawing & Sealing Joints	50,304 LF @ \$1.59	\$ 79,983
Diamond Grinding	16,768 SY @ \$7.00/SY	<u>117,376</u>
	Subtotal	\$197,359

(0.5% of Travel Lanes – 11 Panels)

Remove and Replace PCCP	168 SY @ \$86.00/SY	\$14,448
Sawing & Sealing Joints	528 LF @ \$1.59	\$ 840
Diamond Grinding	176 SY @ \$7.00/SY	<u>1,232</u>
	Subtotal	\$16,520

Traffic Control	30 Days @ \$1,000/Day	<u>\$30,000</u>
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Total of Items Above	\$243,879
CE Cost (23.95%)	<u>58,409</u>
Total at Year 22	\$302,288
PWF (4.99 % in year 22)	\$ 15,084

The DRB used the same formula for Price reduction that was presented at the Hearing which results in the following Price Reduction.

Price Reduction = Midpoint of Options 4a and 4b plus Option 5

$$= \quad \$137,436 \quad + \quad \$15,084 = \underline{\underline{\$152,520}}$$

Respectfully submitted, this 9th Day of April 2010

L.G. Duncan

Stanley B. Williams

W. H. Hinton II

Attachments:

1. Exhibit Lists
2. CDOT White Paper
3. CRCC Price Reduction Comparison
4. Paul Okamoto Presentation
5. Parties' Agreement on March 1, 2010

ATTACHMENT 1

**Castle Rock Construction Company
List of Documents**

0001 – 0006 CRCC's Rehabilitation Costs / Invoices

CRCC started paving the 8½" PCCP in the Frontage Road on June 11, 2009. Paving completed July 22, 2009.

0007 – CTS / Cesare Field Observation Report

0008 – 0056 August 10th CDOT performed 1st MIT scans of the pavement. Again on the 13th.

0001 August 31st CRCC removed and replaced 229' x 12' = 305 sy of pavement found to have no load transfer devices.

0003 September 3rd CPSS retrofitted 30 each 1" dowel bars @ 47.50 / each. 5 joints. Note: CPSS's 205 was submitted August 4th.

0057 September 15th CRCC informs CDOT of retrofit completion (and contemplates no further action).

September 24th CRCC meets with CDOT to discuss scan findings.

0058 October 2nd CDOT informs LCCo of the withholding of the September Estimate.

0059 October 3rd CRCC offers a 10 year warranty on the pavement.

0060 October 23rd CDOT issues CMO #16 for PCCP not meeting specs in the amount of (\$202,842.89).

0061 October 30th CRCC issues a Notice of Dispute (in response to CMO #16).

0062 – 0076 November 3rd CDOT performs additional (random) MIT scans. These are the basis of CDOT's Dowel Bar Assessment.

0077 – 0078 November 11th CRCC issues its Request for Equitable Adjustment.

0079 – 0088 December 4th CDOT issues its Assessment and Proposed Price Adjustment. \$194,240 to \$393,887

December 9th CDOT, CRCC & LCCo meet to discuss the Assessment.

0089 December 16th CRCC proposes a \$72,000 price reduction.

0090 – 0092 December 22nd CDOT counters with a proposed \$252,000 price reduction.

December 23rd CRCC requests that LCCo initiate the DRB process.

ATTACHMENT 1

**I-25 Frontage Rd and 8-Laning
CDOT Project C 0252-390 (PCN 16025)
Dispute Review Board Hearing
Scheduled for February 17, 2010**

Item	Pages
Index	000
CDOT Pre-Hearing Position Paper	001-003
CDOT White Paper – Assessment of the I-25/Castle Pines Frontage Road and Proposed Price Adjustment	004-049
Written Correspondence	050-06
Project Speed Memos	065-078
Email Correspondence	079-099
Weekly Progress Meeting Minutes	100-105

ATTACHMENT 2

CDOT White Paper

Dowel Assessment SA#16025 December 4, 2009

Assessment of the I-25/Castle Pines Frontage Road and Proposed Price Adjustment

Based on Statistical Sampling, NCHRP Report 637 Calculation of d_{eq} , and Mechanistic Empirical Performance Modeling

Introduction

During the 2009 construction season, CDOT administered the construction of a PCCP frontage road for Douglas County. Lawrence Construction Company was the prime contractor and Castle Rock Construction Company (CRCC) was the paving contractor. Dowel bar inserter (DBI) problems were noted by CDOT inspectors during paving operations. The contractor did not perform their Quality Control check of the dowel bars until all of the PCCP paving was completed. The instrument required for checking the dowel bars is not specified in the project specifications. The contractor utilized a cover meter which detected joints on the project without dowel bars. At that time CDOT brought out a Magnetic Imaging Technology (MIT) device and documented dowel bar misplacements in the joints that were tested. Upon additional testing it was then determined that dowel bar misalignments beyond the specification tolerances exist throughout the project and some areas were missing dowel bars altogether. A final field sampling was conducted on November 3, 2009 to generate the data used in this assessment. The objectives of this assessment are to detail the overall quality of dowel bar placement on the project, to determine the impact of bar misalignment on the long term performance of the frontage road pavement, and to recommend options to allow project acceptance.

Field Sampling and Statistical Data Analysis

Field sampling for this assessment was conducted on November 3, 2009 by representatives of CDOT Region One Materials, CDOT Staff Materials Concrete/Physical Properties Program, and the CDOT Arapahoe Residency using CDOT's MIT device. Field data collection and raw data processing were completed by Eric Prieve, Staff Materials Concrete Program. Statistical processing of the resulting Excel data was completed by Bill Schiebel, CDOT Region One Materials Engineer. In order to ensure statistical validity of the MIT data in representing the DBI placements on the project, sampling was conducted in keeping with the Central Limit Theorem. A minimum of 30 random samples were required to statistically model the entire population of DBI-installed 12-foot doweled joints on the project. CDOT collected MIT data for 50 randomly selected joint locations on the frontage road.

The data was analyzed to quantify CRCC's overall placement of dowel bars where their paver's DBI equipment was utilized. Four joint locations tested were installed using dowel bar baskets and were removed from the final analysis. Three tested joints had no dowels and were also removed from analysis for determining the typical DBI misalignment. In summary for the DBI-installed joints on the project: 6% of project joints are estimated to have no dowel bars in place; in the joints where dowels were placed, there is a 95.4% confidence that the project bar depths are within 1.42" of the mid-slab location, side shifts are less than 6.79", skews are less than 2.54", and minimum cover is more than 2.82". See the attached "Summary Data" sheet for complete statistical data.

Dowel Assessment SA#16025 December 4, 2009

NCHRP Report 637 Data Analysis

The National Cooperative Highway Research Program (NCHRP) Report 637 entitled "Guidelines for Dowel Alignment in Concrete Pavements" is the latest research report from the Transportation Research Board on this subject. The report includes recommended practices for calculating the performance impacts of misaligned dowel bars measured from field values for skew, side shift, and depth. These values are used to compute overall equivalent dowel bar diameter, d_{eq} . The computed d_{eq} decreases with increasing bar misalignment. The calculated reduced bar diameters and load transfer efficiencies (LTE) are then put into the Mechanistic Empirical Pavement Design Guide (MEPDG) program and projected long term performance impacts are modeled. For this project, the calculated d_{eq} is approximately 0.4". This calculated reduced diameter represents the limits of the 95.4% confidence range. To utilize a typical manufactured bar size and to discount potential errors in depth measurements due to varying bar diameters, half-inch bars will be targeted in the modeling estimates from the MEPDG. Bill Schiebel completed the d_{eq} analysis in Excel. See the attached "Equivalent Diameter" calculation summary sheet.

MEPDG Performance Modeling

Actual field soils test data was used to model the embankment. The distribution of truck classes was set

DISPUTE REVIEW BOARD REPORT AND RECOMMENDATION

CDOT PROJECT NO. C 0252-390

Page 12 of 21

to the same as for the adjacent interstate distribution and the Average Annual Daily Truck Traffic of 200 was applied for this project. Centennial Airport weather data and the concrete mix properties from CRCC's mix design were also input. Level 3 inputs were used for the PCCP and level 2 for the two modeled soils layers. The MEPDG performance analysis was run by Jay Goldbaum, CDOT Pavement Design Program Manager. See the attached MEPDG "Input Summary" and the plots showing performance estimates of "Predicted Cracking, Predicted Faulting, and Predicted IRI".

Performance Summary

The MEPDG inputs allow for bar sizes to 1" minimum. To allow for extrapolation to the half-inch reduced diameter size from the NCHRP calculations, 1.5", 1.25" and 1" sizes were modeled. In addition, performance was also modeled for the condition of no dowel bars in the pavement. Distress levels were then estimated through extrapolation to the half-inch size. MEPDG data predicts no cracking for any bar size or with no bars modeled. Predicted faulting for the model with no dowel bars is expected to reach the 0.12" performance limit at year 26. According to CDOT life cycle cost analysis (LCCA) procedures, planned rehabilitation work (diamond grinding and ½ % slab replacement) is typically scheduled for year 22. At year 22 the regularly scheduled rehabilitation including ½ % slab replacement, 0.25" diamond grinding for 50% of the travel lanes, and joint resealing is recommended for CDOT PCCP roadways. The predicted IRI is the distress category where poor bar installation yields a significant impact on the year at which the performance limit is reached. According to the predicted IRI values, the 6% unreinforced panels will exceed the performance limit at year nine. The remaining pavement will have locations that Dowel Assessment SA#16025 December 4, 2009 will exceed the performance limit at year 17 instead of year 22. Again, based on the statistical modeling this IRI condition at year 17 is anticipated at various locations within the project with 95.4% confidence.

Recommendations

NCHRP Report 637 discusses and makes recommendations for dowel bar rejection tolerances. These could be used to compute the total number of joints that exceed rejection tolerances and, as such, are eligible for no or reduced pay. The project contract requirement was to place 10 dowel bars in each joint. Some industry representatives believe that a minimum of six dowels per joint yields sufficient load transfer across the joint. Considering only six total bars in each joint to facilitate load transfer, and therefore averaging the highest six percentages of bars within the reject tolerances, 34% of the joints are estimated to fall outside the Report 637 rejection tolerances. See the attached "Rejection Tolerances" data sheet for information. Acceptance of the DBI pavement in its current condition could be made at 66% pay. Alternative price reduction options could be considered to this option and are discussed below.

The joints with misaligned bars in them are not predicted to exceed the cracking or faulting performance limits. With 95.4% confidence and at various locations throughout the frontage road, the IRI is expected to reach the performance limit at approximately year 17 rather than at the year of typical recommended rehabilitation - year 22. The loss in value for this pavement could be estimated as equivalent to the loss in five years of performance life. That is a 16.7% loss on a 30-year design life for the portions of the project where dowels were installed using the DBI. A price reduction is recommended for the panels in this category.

Six percent of the joints on the project are estimated to have no dowel bars. The faulting performance limit will be reached in year 26 and ride performance will reach the performance limit of 175 inches per mile by year nine. CDOT could leave these in place and perform panel replacement work as the IRI issues arise. Full price reduction is recommended for the panels in this category.

In general, the predicted performance of the pavement is lower than that for a PCCP pavement with dowel bars properly installed within the CDOT specifications. Price reduction could be based on composite calculations including the following options:

1. 34% Pay Reduction for full DBI pavement based on dowel rejection tolerances

The price reduction amount for this option is \$304,367

2. 16.7% Pay Reduction for full DBI pavement based on five year loss of IRI design life

The price reduction amount for this option is \$140,528

3. 6% Pay Reduction for the panels where no dowels exist

The price reduction amount for this option is \$53,712

The Project Engineer may consider these price reduction options during the process of completing project acceptance. Options 2 and 3 should be combined into a single price reduction to account for the types of distresses reflected in both options.

CDOT Unit Pricing		CMCC Unit Pricing		
<p>(Option 4a) Remove & Replace 6% of Affected Panels (S.A., Placed with db) Remove & Replace 0% Traffic Control Routing & Sealing Diamond Grinding</p>				<p>0 days \$73.00 / sq yd \$140,855 2,016 sq yd \$1,000 / day \$2,016,000 2,016 sq yd \$1.70 / sq yd \$3,427 2,016 sq yd \$3.05 / sq yd \$6,158 \$152,429 Subtotal (Design & Misc Excluded) \$23,552 CE Cost (23.99%) \$281,338 \$118,383 P/WF (74.88% in Year 0)</p>
<p>(Option 4b) Retrofit & Diamond Grind 6% of Affected Panels (L.A., Placed with db) Spalling (Less than Retrofitting) Traffic Control Routing & Sealing Diamond Grinding</p>				<p>756 bars \$40 / bar \$30,240 6 days \$1,000 / day \$6,000 2,016 sq yd \$1.70 / sq yd \$3,427 2,016 sq yd \$3.05 / sq yd \$6,158 \$45,825 \$10,873 CE Cost (23.86%) \$59,799 \$42,490 P/WF (74.88% in Year 0)</p>
<p>(Option 5) Difference in Cost of Rehabilitation at Year 17 Instead of Year 22</p>				<p>4 days \$1,000 / day \$4,000 16,768 sq yd \$1.70 / sq yd \$28,506 16,768 sq yd \$3.05 / sq yd \$50,943 \$83,452 Includes Traffic Control \$50,943 Subtotal (Design & Misc Excluded) \$30,526 CE Cost (23.85%) \$103,978</p>
<p>(Option 6) 6.6% of Travel Lanes (11 Panels)</p>				<p>1 days \$73.00 / sq yd \$73,000 179 sq yd \$1,000 / day \$179,000 179 sq yd \$1.70 / sq yd \$304.30 179 sq yd \$3.05 / sq yd \$542.45 \$14,074 Subtotal (Design & Misc Excluded) \$3,323 CE Cost (23.86%) \$17,444 \$121,126 Total at Year 22 \$10,417 6.0% of \$694,224</p>
<p>(Option 4a) Remove & Replace 6% of Affected Panels (S.A., Placed with db) Remove & Replace 0% Traffic Control Routing & Sealing Diamond Grinding</p>		<p>0.06 33,658 sq yd \$100 / sq yd \$3,365,800 30 days \$1,000 / day \$30,000 4 sides \$5 / LF \$20,000 12 8 sides \$15 / sq yd \$1,440 \$3,385,800 Subtotal (Design & Misc Excluded) \$66,690 CE Cost (23.52%) \$381,496 \$285,906 P/WF (74.88% in Year 0)</p>	<p>126 joints \$45 / bar \$5,670 30 days \$1,000 / day \$30,000 4 sides \$5 / LF \$20,000 12 8 sides \$15 / sq yd \$1,440 \$57,110 \$12,838 CE Cost (22.52%) \$154,318 \$112,244 P/WF (74.88% in Year 0)</p>	
<p>(Option 5) Difference in Cost of Rehabilitation at Year 17 Instead of Year 22</p>		<p>30 days \$1,000 / day \$30,000 4 sides \$5 / LF \$20,000 12 8 sides \$15 / sq yd \$1,440 \$51,440 Subtotal (Design & Misc Excluded) \$27,803 CE Cost (23.09%) \$89,243</p>	<p>1 days \$73.00 / sq yd \$73,000 179 sq yd \$1,000 / day \$179,000 179 sq yd \$1.70 / sq yd \$304.30 179 sq yd \$3.05 / sq yd \$542.45 \$14,074 Subtotal (Design & Misc Excluded) \$3,323 CE Cost (23.86%) \$17,444 \$121,126 Total at Year 22 \$10,417 6.0% of \$694,224 (DB in P/WF for Yr 17 vs Yr 22 = 0.2703 = 0.4832)</p>	

Midpoint of Options 4a and 4b: (\$162,600) plus Options 5 & 6 (\$16,417) = \$166,796

Midpoint of Options 4a and 4b: (\$162,600) plus Options 5 & 6 (\$89,793) = \$128,289

ATTACHMENT 4

Dowel Bar Alignment Analysis

CDOT Testing

- 50 randomly selected joints tested with MIT scan equipment
 - depth (concrete cover)
 - vertical alignment (tilt)
 - horizontal alignment (skew)
 - embedment length
- 3 joints excluded (no dowel bars) and 4 joints excluded that were placed using basket assemblies

CDOT Analysis

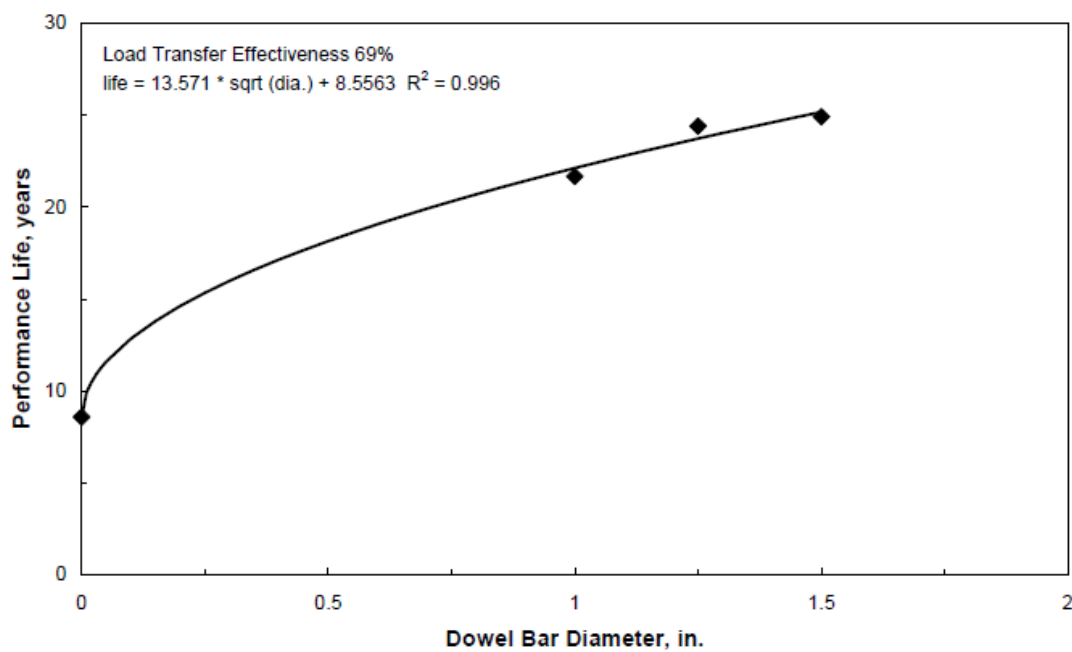
- Two different analyses
 - missing dowel bars
 - dowel bar misalignment
- Joints with no dowel bars (3 of 50 joints, 6%)
 - Roughness limit (172 in./mi) met at 17 years (expected as-constructed performance life)
- Joints with dowel bars (43 of 50 joints)
 - Roughness limit met at 17 years (expected as-constructed performance life)

NCHRP 637 Procedure

- Dowel bar diameter adjustment factor accounting for
 - embedment length adjustment factor is a function embedment length
 - concrete cover reduction factor is a function of slab thickness, dowel diameter, as constructed cover, and assumed typical variability factor (1/2 in.)
- Dowel bar diameter adjustment factor accounting for
 - rotation (vertical tilt and horizontal skew) adjustment factor is a function of dowel diameter, average rotation, standard deviation of rotation (effects of variability), and maximum rotation in critical wheel path
- Dowel bar adjustment factor
$$d = \text{remb} * \text{rcc} * \text{rvt} * \text{rhs} * \text{dowel diameter}$$
- Use reduced dowel bar diameter in the AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG) to model expected pavement performance

Service Life (CTLGroup)

Dowel Diameter vs. Performance

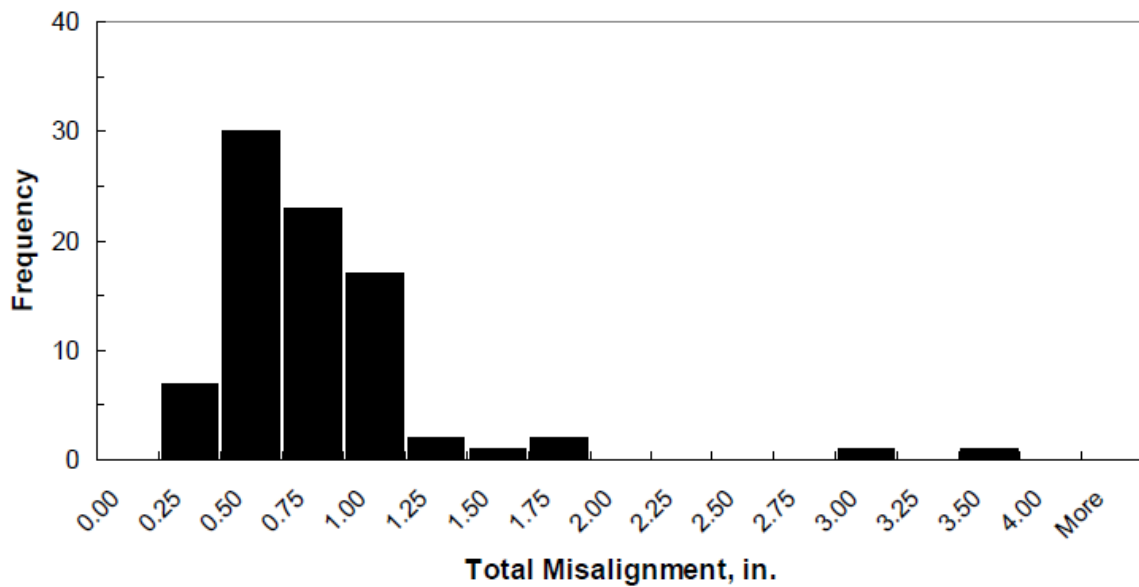


Vertical and Horizontal Misalignment

- Rotation (vertical tilt and horizontal skew) adjustment factor is a function of dowel diameter, average rotation, standard deviation of rotation (effects of variability), and maximum rotation in critical wheel path

Critical Wheel Path Total Misalignment

Total Misalignment Bars #1 & #2



Eliminate Bars in Wheel Path

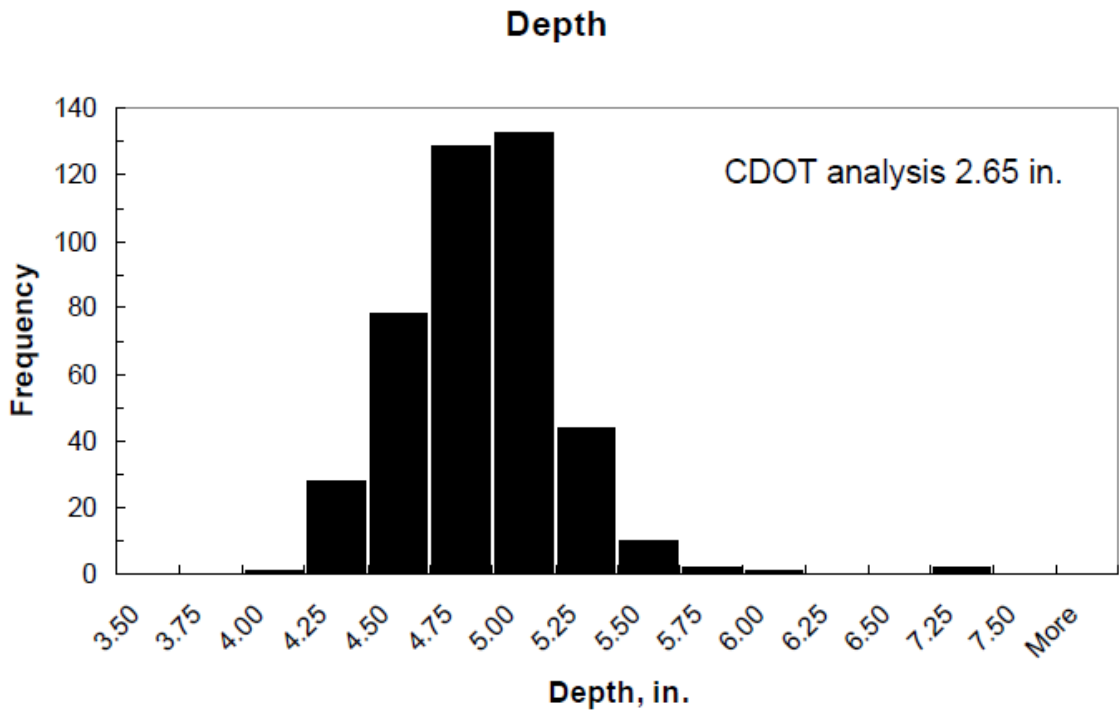
Eliminated	Tilt _{max} , in.	Dia. _{eq} , in	Life, yrs
all data	3.39	0.35	17
1 bar	2.75	0.42	17
2 bars	1.56	0.53	18
3 bars	1.52	0.54	19
4 bars	1.35	0.54	19
5 bars	1.10	0.57	19

6 bars	1.10	0.59	19
7 bars	1.09	0.60	19
8 bars	0.99	0.61	19

Confidence Intervals

- Use conservative dowel bar data less than the average
- CDOT utilized 95% confidence interval (two-sided) 97.5% of the population will perform better than predicted
 - concrete cover 2.65 in.
 - embedment length 3.05 in.

95% confidence Interval



Confidence Intervals

One-Sided CI	L _{emb} , in.	Dia. _{eq} , in	Life, yrs
95%	3.98	0.70	20
	5.17	0.78	21

ATTACHMENT 5

STATE OF COLORADO

DEPARTMENT OF TRANSPORTATION

Region 1 – Arapahoe Residency

7328 South Revere Parkway, Suite 204A

Centennial, Colorado 80112

Phone 303-365-7230 Fax 303-790-1037

C:\Projects\JaureguiRoman\ProjectsActive_Region1\025WideningAndFrontageRoad#16025\ConferenceCallOutcomeReDowelBarAnalysis_16025.doc

March 2, 2010 Project C 0252-390

I-25 Frontage Rd & 8-Laning

PCN 16025

Mr. Bill Hinton

Dispute Review Board Chairman

428 Kearney St.

Denver, CO 80220

Re: Outcome of Conference Call to Discuss Dowel Bar Analysis

Dear Mr. Hinton:

As agreed during the DRB hearing of February 17th, the conference call between the experts to discuss the dowel bar analysis and the resulting pavement performance has been completed. The conference call occurred on Monday, March 1, 2010, from 12:35 p.m. to 1:05 p.m. In attendance at CDOT's North Holly location were Messrs. Bill Schiebel, Jay Goldbaum and Roman Jauregui representing CDOT and Mr. Greg Nejezchleb representing CRCC. In attendance via conference call was Mr. Paul Okamoto of CTL Group representing CRCC.

Discussed were the dowel bar and pavement analysis conducted by CDOT and the subsequent analysis conducted by CTL Group which was provided to CDOT on the morning of March 1st. In summary, the CDOT and CTL Group analyses differ in methodology but result in similar outcomes. The CDOT analysis modeled the performance of a statistically representative joint for the 95% confidence interval based on all of the joints tested. The CTL Group analysis modeled the performance of each individual joint tested then made statistical evaluation of the resulting performance of those joints. The outcome for performance life from either methodology appears to be very similar for the 0.4" equivalent bar diameter initially determined in the CDOT analysis.

In addition, the appropriate confidence interval (CI) to use when assessing joint performance was discussed during the DRB hearing. CDOT's initial analysis proposed a CI of 95%. During the conference call, it was agreed to use the CTL Group analysis with a CI of 90%. This CI corresponds to the 90% reliability factor used in the MEPDG modeling. Based on a CI of 90%, the following was concluded:

- The Year 17 rehabilitation in CDOT's initial Option 5 can be delayed until Year 19.5;
- The group concurred that Year 19 should be used, instead of Year 19.5, in accordance with standard practice for conducting rehabilitation. Rounding the year down will

DISPUTE REVIEW BOARD REPORT AND RECOMMENDATION

CDOT PROJECT NO. C 0252-390

Page 20 of 21

prevent public use of a distressed pavement;

- The present worth difference for rehabilitation in Year 19 is 4.99% versus a present worth difference for Year 17 of 8.6% (both years are compared to Year 22 as shown in CDOT's initial analysis);
- The total cost of Option 5 changes from \$59,703 to \$34,642 based on CDOT costs and changes from \$10,417 to \$6,044 based on CRCC costs (see attachment); and
- The overall proposed CDOT price reduction changes from \$252,308 to \$227,247. Using CRCC's unit prices with the same approach as CDOT, the CRCC price reduction changes from \$106,798 to \$102,425.

Attached are the revised cost comparison sheet from CRCC (showing costs for Options 4a, 4b, and 5) and the analysis document provided by CTL Group. This concludes the final recommendations from the analysis efforts by the experts on this project. Please feel free to contact me with any questions or comments.

Sincerely,
Roman Jauregui
Resident Engineer

Attachments: Revised Spreadsheet Comparing Costs (1 page)
CTL Group Letter of Analysis (15 pages)

Copy: M.Bliven, Lawrence Construction Company
G.Nejezchleb, Castle Rock Construction Company
P.Okamoto, CTL Group
C.DeJiacomo, Program Engineer
B.Schiebel, Region Materials Engineer
J.Goldbaum, Pavement Design Program Manager

DISPUTE REVIEW BOARD REPORT AND RECOMMENDATION

CDOT PROJECT NO. C 0252-390

COST Unit Pricing		CROSS Unit Pricing	
<p>Option 4a) Remove & Replace 6% of Affected Panels (i.e., Paved with 48)</p>			
<p>Remove & Replace 6% Traffic Control Routing & Sealing Diamond Grinding</p>	<p>0.06 30 days 4 shifts 12 ft/side 12 ft/side</p>	<p>\$100 / sq yd \$1,000 / day \$5 / LF \$15 / sq yd</p>	<p>\$20,000 / sq yd \$4,000 / day \$1,700 / sq yd \$3,000 / sq yd \$193,420 Subtotal (Design & Mobil Excluded) \$28,850 CE Cost (23.85%) \$21,470 PWF (74.85% in Year 0) \$288,940 Total at Year 0</p>
<p>Option 4b) Remove & Replace 6% of Affected Panels (i.e., Paved with 48)</p>			
<p>Subtotal (Less than Retaining) Traffic Control Routing & Sealing Diamond Grinding</p>	<p>6 joints 30 days 4 shifts 12 ft/side 12 ft/side</p>	<p>\$45 / bar \$1,000 / day \$5 / LF \$15 / sq yd</p>	<p>\$30,240 \$3,000 / day \$3,420 \$6,120 \$45,000 Subtotal (Design & Mobil Excluded) \$28,850 CE Cost (23.85%) \$116,240 PWF (74.85% in Year 0)</p>
<p>Option 5) Difference in Cost of Rehabilitation of Year 19 Instead of Year 22</p>			
<p>60% of Travel Lanes (1848 Panels)</p>			
<p>Traffic Control Routing & Sealing Diamond Grinding</p>	<p>30 days 4 shifts 12 ft/side 12 ft/side</p>	<p>\$1,000 / day \$5 / LF \$15 / sq yd</p>	<p>\$4,000 \$3,000 \$27,000 Subtotal (Design & Mobil Excluded) \$37,000 CE Cost (23.95%) \$89,000 Total at Year 22</p>
<p>6.6% of Travel Lanes (71 Panels)</p>			
<p>Remove & Replace 0.5% Traffic Control Routing & Sealing Diamond Grinding</p>	<p>0.006 6 days 4 shifts 12 ft/side 12 ft/side</p>	<p>\$100 / sq yd \$1,000 / day \$5 / LF \$15 / sq yd</p>	<p>\$12,200 \$1,500 / day \$2,000 \$3,300 Subtotal (Design & Mobil Excluded) \$2,270 CE Cost (23.95%) \$17,440 Total at Year 22</p>
<p>Option 6) Difference in Cost of Rehabilitation of Year 19 Instead of Year 22</p>			
<p>60% of Travel Lanes (1848 Panels)</p>			
<p>Traffic Control Routing & Sealing Diamond Grinding</p>	<p>30 days 4 shifts 12 ft/side 12 ft/side</p>	<p>\$1,000 / day \$5 / LF \$15 / sq yd</p>	<p>\$4,000 \$3,000 \$27,000 Subtotal (Design & Mobil Excluded) \$37,000 CE Cost (23.95%) \$89,000 Total at Year 22</p>
<p>6.6% of Travel Lanes (71 Panels)</p>			
<p>Remove & Replace 0.5% Traffic Control Routing & Sealing Diamond Grinding</p>	<p>0.006 6 days 4 shifts 12 ft/side 12 ft/side</p>	<p>\$100 / sq yd \$1,000 / day \$5 / LF \$15 / sq yd</p>	<p>\$12,200 \$1,500 / day \$2,000 \$3,300 Subtotal (Design & Mobil Excluded) \$2,270 CE Cost (23.95%) \$17,440 Total at Year 22</p>

Multiples of Options 4a and 4b (1848,381) plus Options 5 (16,042) = 1762,425

Multiples of Options 4a and 4b (1848,345) plus Options 5 (16,042) = 1927,347