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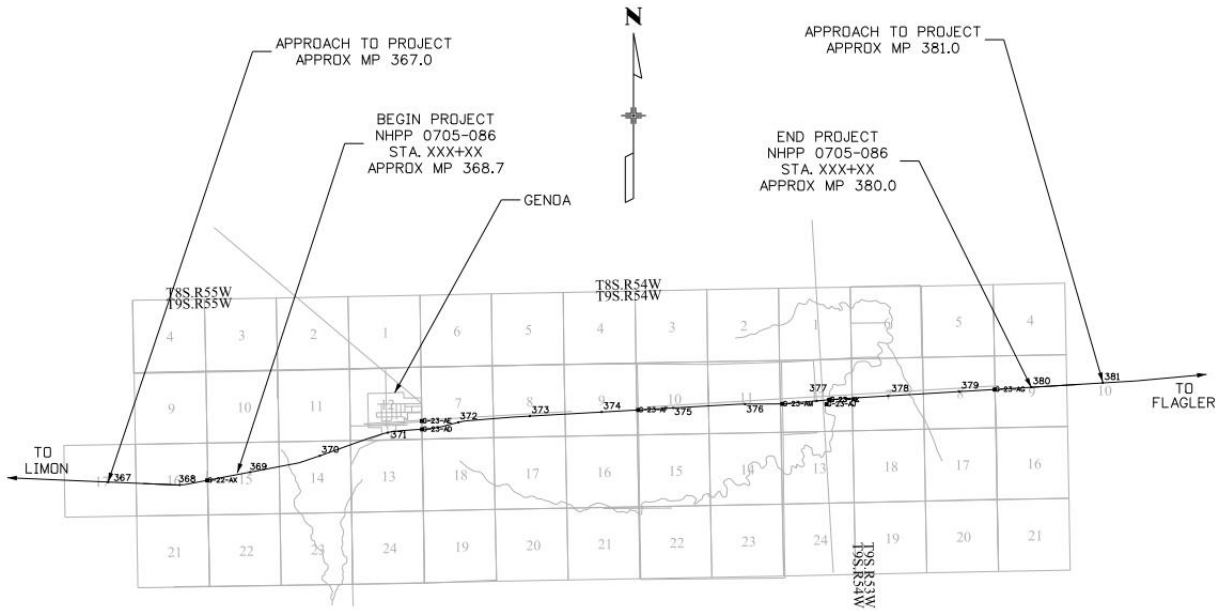
# 22463 I-70 Genoa East and West Pavement Reconstruction Project

# Final Value Engineering Report




**Prepared For:**

COLORADO
Department of Transportation

**Date:** **January 2020**

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# 1. Executive Summary

## 1.1 Introduction

AECOM was retained to undertake a 4-day Value Engineering (VE) Study for the 22463 I-70 Genoa East and West Pavement Reconstruction Project. The project cost estimate is $49.3M based on the Colorado Department of Transportation (CDOT) Preliminary Detail Cost Estimate.

The Value Engineering Study was undertaken based on the scope of work and the SAVE International Value Engineering Methodology, which includes three stages: (1) Pre-Workshop; (2) Workshop; and, (3) Post-Workshop. The workshop portion of the VE Study followed the six-phase VE Job Plan consisting of: (1) Information Phase; (2) Function Analysis Phase; (3) Creative Phase; (4) Evaluation Phase; (5) Development Phase; and, (6) Presentation Phase. A detailed description of the VE Study process is provided in **Section 5** of this report. The Information Phase was held on July 8th, 2019, in Limon, CO. The VE Workshop was held from July 9th to July 12th, 2019 at AECOM's office in Greenwood Village, CO. The VE Results Presentation was held on the morning of July 19th, 2019 at AECOM office in Greenwood Village, CO.

The Pareto Cost Models developed during the Pre-Workshop Stage are provided in **Appendix A**. The results of the Function Analysis Phase are provided in **Appendix B**. Ideas generated and evaluated during the Creative Phase and the Evaluation Phase are provided in **Appendix C**. **Appendix D** provides the Pre-Workshop Pavement Analysis undertaken by the VE Team's pavement subject matter expert. **Appendix E** provides further details on the CDOT's disposition of the VE Proposals and Design Comments.

## 1.2 Overview of the Project

22463 I-70 Genoa Pavement Rehabilitation Project begins approximately 5.5 miles east of Limon at MP 368.7 and continues east for 11.3 miles ending at MP 380.0 on Interstate 70 (**Figure 1**). The existing roadway is a highly distressed hot mix asphalt (HMA) surface. The condition of the roadway pavement structure is worse in the westbound direction compared to the eastbound direction. The subbases are also very different throughout the length of the project. Within the two directions of travel the distresses in the driving lane (Lane 2) varies greatly from the passing lane (Lane 1) as well.

The current design being proposed is a 1" milling of the existing surface followed with 9.5" concrete pavement using 1.5" dowel bars. The 1" milling of the concrete surface is to roughen the surface without destabilizing the potentially degraded HMA below. Further information on the base case design is provided in **Section 3** of this report.

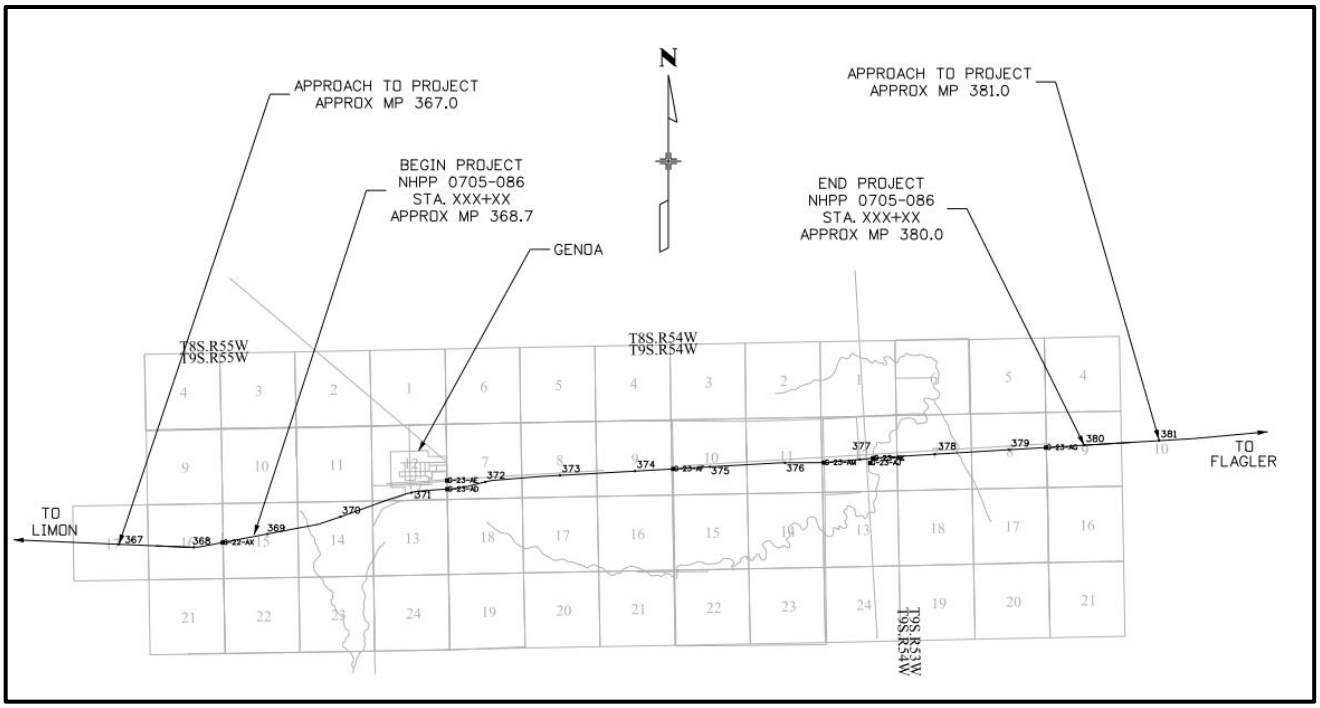



**Figure 1: 22463 I-70 Genoa East and West Pavement Rehabilitation Project Study**

## 1.3 Value Engineering (VE) Team

A multi-disciplinary team of subject matter experts was assembled for this assignment. **Table 1** provides the VE Team and Resource Team members.

**Table 1: VE Team and Resource Team Members**

| Name | Discipline | Company | Team |
|---|---|---|---|
| Tammy Dow, CVS | Certified Value Specialist | AECOM | VE |
| Steve McQuilkin, PE | Senior Engineer/Project Manager | AECOM | VE |
| Jay Goldbaun, PE | Senior Pavement Design Engineer | RockSol | VE |
| Mike Heugh, PE | MOT/Traffic Engineer | AECOM | VE |
| Travis Miller, PE | Limon Resident Engineer | CDOT | Resource |
| Rhianna Poss, P.E. | Project Manager | CDOT | Resource |
| Karl Larson | Construction and Design | CDOT | Resource |

## 1.4 Objectives of the VE Study

The goals and objectives of the VE Study were discussed during the Information Phase of the VE Workshop and include:

- Review the 60% Design with respect to cost-effectiveness, function and the ability to meet project objectives
- To provide VE Proposals and Design Comments to increase project value through innovative ideas that improve functionality, improve schedule, improve constructability, and/or capital cost avoidance while maintaining quality and functionality

## 1.5 Highlights of the VE Study

During the Creative Phase, the VE Team brainstormed ways to improve value in the project, generating **60** creative ideas. The results of VE Study are presented in **9** VE Proposals, which are individual alternatives for elements of the project. These VE Proposals are documented in **Section 4** of this report and were developed from selected creative ideas as discussed in **Section 5**. In addition, there are **10** Design Comments for which definitive VE Proposals could not be made or quantified at the time of the VE Study.

**Table 2** presents a summary of the ideas developed into VE Proposals and Design Comments, with cost implications, where applicable. The cost estimates for the VE Proposals were developed consistent to the cost estimate parameters used in the CDOT Preliminary Detail Cost Estimate. Based on discussions with CDOT staff, a 30 % mark-up (5.5% for mobilization, 5% for minor contract revisions (MCR) and 18.66% for Construction Engineering for a total of 29.16%, which was rounded up to 30%), was used.

In **Table 2**, only the ideas developed as VE Proposals and Design Comments are provided. The complete list of creative ideas and their evaluation is provided in the Summary of Creative Ideas and Evaluation Table in **Appendix C** of this report.

**Table 2: Summary of VE Proposals and Design Comments**

| VE Proposal or Design Comment No. | Idea No. | Description | Cost Savings (Additional Costs) |
|---|---|---|---|
| VE-1 | 1 | Accelerate schedule | ($2,530,707) |
| VE-2 | 3 | Re-evaluate the concrete design | $3,467,965 |
| VE-3 | 4 | Optimize milling | $620,466 |
| VE-4 | 12 | Use widened lanes | $3,305,025 |
| VE-5 | 13 | Minimal vertical clearances at the bridges | $1,605,710 |
| VE-6 | 17 | Use higher strength concrete | $2,997,599 |
| VE-7 | 23 | Use millings generated on project for subbase material | $104,317 |
| VE-8 | 45 | Reuse unsuitable material for shouldering | $444,450 |
| VE-9 | 54 | Reduce concrete thickness by using shorter panels | $1,270,883 |
| DC-1 | 5 | Temporary ramp closures | - |
| DC-2 | 16 | Use innovative to CDOT concrete mixtures | - |
| DC-3 | 20 | Improve channelizing devices | - |
| DC-4 | 21 | Use portable rumble strips during construction | - |
| DC-5 | 28 | Modify density requirements for top 6" of shoulders | - |
| DC-6 | 31 | Allow a temporary on and off ramp for construction vehicles close to center of project | - |
| DC-7 | 42 | Use thin white topping | - |

| VE Proposal or Design Comment No. | Idea No. | Description | Cost Savings (Additional Costs) |
|---|---|---|---|
| DC-8 | 44 | Reduce initial International Roughness Index (IRI) to 70 to achieve smoother pavement and reduce pavement thickness | - |
| DC-9 | 58 | Undertake Falling Weight Deflectometer (FWD) analysis | - |
| DC-10 | 59 | Undertake Ground Penetrating Radar (GPR) analysis | - |

## 1.6 Disclaimer

A 4-day VE Study was performed for the I-70 Genoa Project. VE Studies are working sessions for the purpose of developing and proposing alternative ideas for projects. As such, the VE Proposals and Design Comments were developed with the resources available and within the timeframe of the 4-day workshop and are based on the information provided to the VE Team at the time of the workshop.

The VE Proposals and Design Comments are conceptual in nature and are not intended as final designs. Feasibility and final design development of any VE Proposals and Design Comments presented herein, should they be accepted, remain the responsibility of CDOT as detailed feasibility of the VE Proposals could not be undertaken at the time of the VE Study due to technical and time limitations. Discussions with respect to the viability of the VE Proposals will need to be undertaken by CDOT. VE Team members will not sign or seal any VE Proposals and Design Comments contained in this report as certifiable engineering or architectural designs.

The cost estimates prepared for this VE Study were developed solely for the purpose of comparing the costs of VE Proposals to the functional equivalent in the base case. The VE Team had limited time and resources to prepare cost estimates for each VE Proposal. Therefore, these cost estimates are not recommended to be used for budgeting or construction purposes. CDOT should more accurately quantify any saving/additional costs of the VE Proposals they accept.

The VE Team takes no responsibility for the implementation of the VE Proposals relative to CDOT design standards, etc. The VE Team does not guarantee the potential monetary savings.

# 2. Implementation Action

## 2.1 Introduction

**Table 3** presents a summary of the ideas developed into VE Proposals and Design Comments. A complete list of the creative ideas and their evaluation is provided in the Summary of Creative Ideas and Evaluation Table in **Appendix C**. All ideas in the **Appendix C** table with a "Carried Forward (CF)" are listed in **Table 3** below as VE Proposals. All ideas in **Appendix C** table with a "Design Comment (DC)" are listed below as Design Comments.

**Table 3** contains CDOTs disposition for each VE Proposal and Design Comment. The following legend was used to document the VE Proposals and Design Comments dispositions:

- A = Accepted
- AM = Accepted with Modifications
- FS = Tabled for Further Study
- R = Reject

**Table 3** also provides the total maximum potential cost savings of the accepted VE Proposals. **Appendix E** provides further information on the CDOTs disposition for each VE Proposal and Design Comment.

## Table 3: VE Proposals and Design Comments Summary and Disposition Table

| VE Proposal or Design Comment No. | Idea No. | Description | Cost Savings (Additional Costs) | Total Accepted Cost Savings | Disposition | Comments |
|---|---|---|---|---|---|---|
| VE-1 | 1 | Accelerate schedule | ($2,530,707) | | R | The additional cost to the project does not outweigh the decreased time benefit |
| VE-2 | 3 | Re-evaluate the concrete design | $3,467,965 | | R | Does not meet design criteria once site specific data is used |
| VE-3 | 4 | Optimize milling | $620,466 | $620,466 | A | |
| VE-4 | 12 | Use widened lanes | $3,305,025 | | R | There is potential risk for longitudinal cracking in slabs <10” in thickness |
| VE-5 | 13 | Minimal vertical clearances at the bridges | $1,605,710 | $1,605,710 | AM | Will need to be redesigned with site specific data |
| VE-6 | 17 | Use higher strength concrete | $2,997,599 | | R | Increased cement can cause brittle PCCP with increased cracking, also data collected from current project shows difficulty meeting the minimum strengths of non high-strength concrete |
| VE-7 | 23 | Use millings generated on project for subbase material | $104,317 | | R | Would not make a stable road base |
| VE-8 | 45 | Reuse unsuitable material for shouldering | $444,450 | $444,450 | A | This is already being done |

| VE Proposal or Design Comment No. | Idea No. | Description | Cost Savings (Additional Costs) | Total Accepted Cost Savings | Disposition | Comments |
|---|---|---|---|---|---|---|
| VE-9 | 54 | Reduce concrete thickness by using shorter panels | $1,270,883 | | R | Increase in future maintenance due to more joints and potential for increased longitudinal cracking |
| | | | **Total Accepted Cost Savings** | **$2,670,626** | | |
| DC-1 | 5 | Temporary ramp closures | - | | A | This is already done in the field |
| DC-2 | 16 | Use innovative to CDOT concrete mixtures | - | | FS | |
| DC-3 | 20 | Improve channelizing devices | - | | FS | |
| DC-4 | 21 | Use portable rumble strips during construction | - | | A | |
| DC-5 | 28 | Modify density requirements for top 6" of shoulders | - | | A | |
| DC-6 | 31 | Allow a temporary on and off ramp for construction vehicles close to center of project | - | | A | This is already done in the field |
| DC-7 | 42 | Use thin white topping | - | | R | |
| DC-8 | 44 | Reduce initial International Roughness Index (IRI) to 70 to achieve smoother pavement and reduce pavement thickness | - | - | FS | |
| DC-9 | 58 | Undertake Falling Weight Deflectometer (FWD) analysis | - | - | FS | |

| VE Proposal or Design Comment No. | Idea No. | Description | Cost Savings (Additional Costs) | Total Accepted Cost Savings | Disposition | Comments |
|---|---|---|---|---|---|---|
| DC-10 | 59 | Undertake Ground Penetrating Radar (GPR) analysis | - | - | FS | |

# 3. Project Overview

## 3.1 Project Description

22463 I-70 Genoa begins approximately 5.5 miles east of Limon at MP 368.7 and continues east for 11.3 miles ending at MP 380.0 on Interstate 70 (**Figure 2**). The current ADT for this stretch of roadway is 11,000 vehicles with 27.2% of those vehicles being trucks. This is a 4-lane roadway. There are 2 lanes with a 4' median shoulder and a 10' outside shoulder making for a total roadway width of 38' in each direction of travel. There are 5 vertically restricted areas within the project limits, 4 overpasses and 1 structure over an unnamed draw in each direction of travel. The terrain in this area is relatively flat with gentle rolling hills and plains.

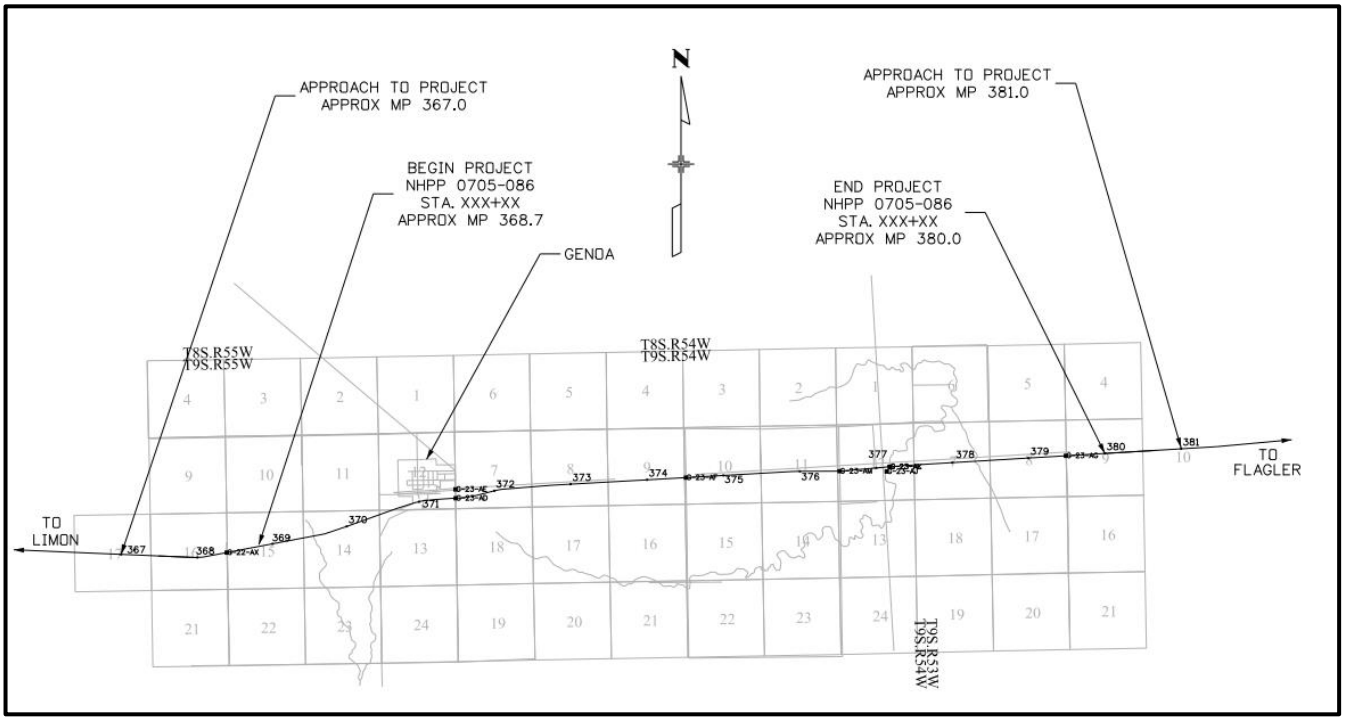



**Figure 2: 22463 I-70 Genoa East and West Pavement Rehabilitation Project Study**

## 3.2 Existing Roadway Characteristics

The existing roadway is highly distressed HMA. The roadway distresses differ greatly in the westbound direction compared to the eastbound direction. The subbases are very different throughout the length of the project. Within the two directions of travel the distresses in the driving lane (Lane 2) varies greatly from the passing lane (Lane 1) as well. The westbound pavement thickness fluctuates from approximately 6" to 24" with an average thickness of 15". The Effective HMA thickness in the westbound direction ranges from a minimum of 1" to a maximum of 17" and has an average effective thickness of 8". The Effective HMA thickness is the amount of HMA that is intact from the surface elevation until you reach the first layer of significant degradation. In the eastbound direction the average HMA thickness is approximately 13" but ranges from 10" to 19".

The Effective HMA thickness ranges from a minimum of 1.5” to 15” and has an average effective thickness of 9” in the eastbound direction. Both directions appear to have base course material primarily A-1-b and A-2-6 varying from 3” to 2’ in depth. Eastbound has a more consistent A-1-b base course. In both directions, the material below the base course is a weak, clay A-6 and A-7-6. Poorer soils were found in the exploratory holes in the eastbound direction than the westbound direction. Sulfate tests indicated water soluble sulfates ranging from 0.0% to 1.4% and thus classifying this area as a Class 2 for Sulfate Exposure.

## 3.3 Base Case Design

The current design being used is a 1” milling of the existing surface followed with 9.5” concrete pavement using 1.5” dowel bars. The 1” milling of the concrete surface is to roughen the surface without destabilizing the potentially degraded HMA below. This thin milling would also remove any shallow surface rutting to minimize uneven support of the concrete pavement. Full depth reconstruction of the pavement structure is required in vertically restricted areas in order to maintain vertical clearance at the structures. The vertically restricted areas have a separate design that differs also in the direction of travel. In the westbound direction where the vertically restricted areas exist, the proposed design is 6” ABC topped with 11” concrete pavement. In the eastbound direction, due to the poor soils that were present, the proposed design is 10” R-40, 6” ABC, and 11” concrete pavement. The proposed ramp design is 6” ABC and 9” concrete pavement and the permanent emergency crossover proposed design is 6” ABC and 9.5” concrete pavement. Typical sections are provided in **Figure 3** and **Figure 4**.

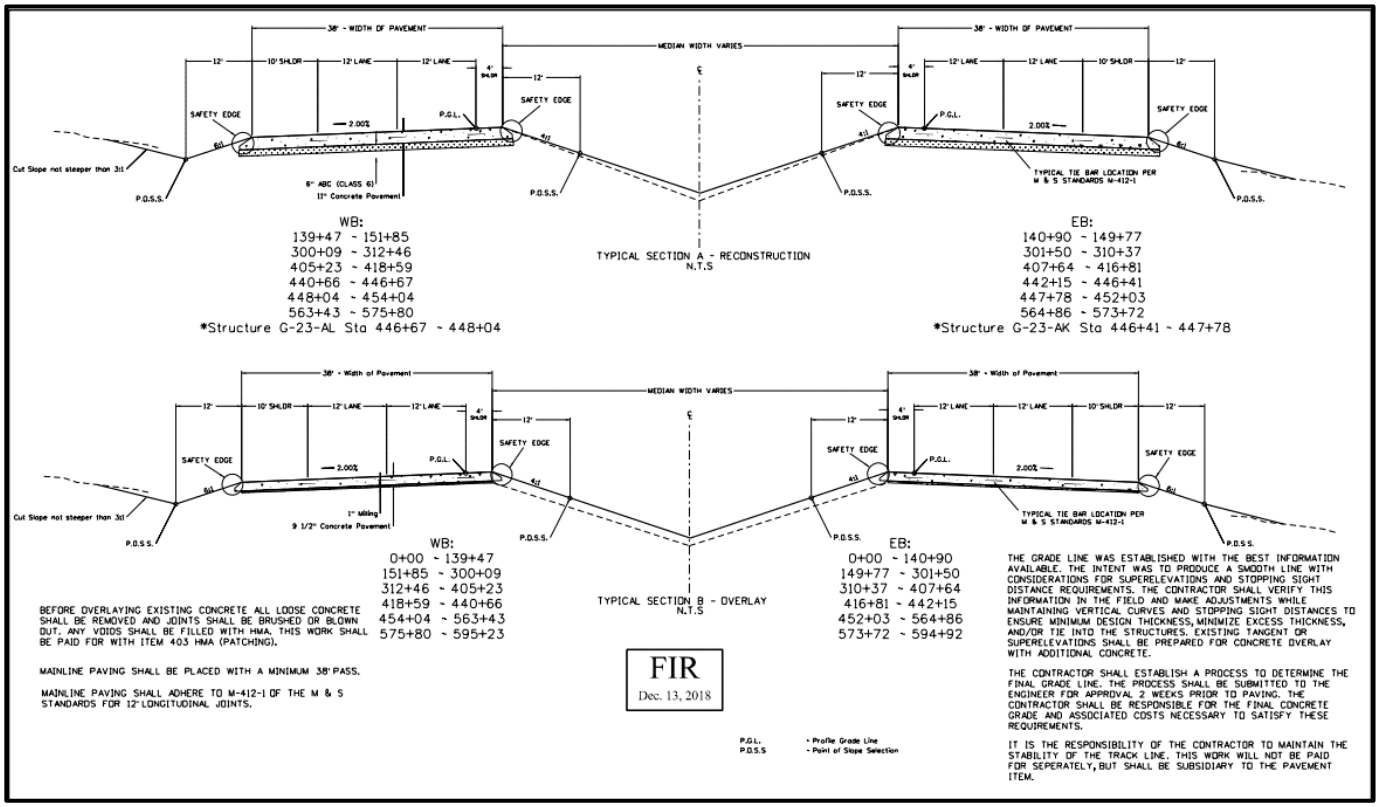



**Figure 3: Typical Cross-Sections**

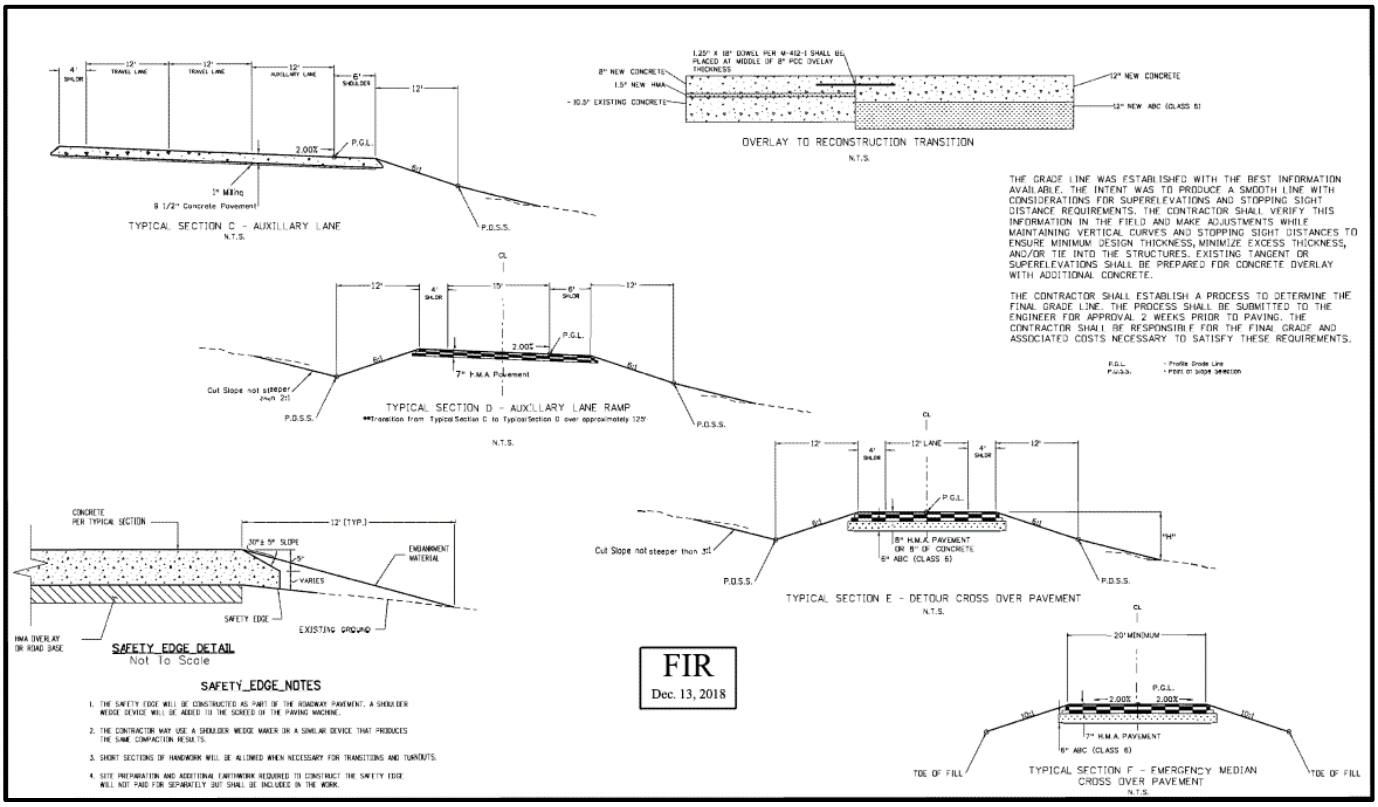



**Figure 4: Typical Cross-Section**

### *3.3.1 Notable Items to Consideration*

With the 2 lanes differing from one another in each direction of travel, there could be some trickiness with the milling. With respect to the vertically restricted areas in the eastbound direction, in order to get to existing elevation, it appears you would need to dig down to a level that would put you in a low strength A-7-6 or A-6 clay. Once opened up it is suspected it would be difficult to re-stabilize without some over excavation. You would need to stabilize with more than 10" R-40 in these areas.

# 4. VE Proposals and Design Comments

## 4.1 Information

During the Creative Phase, the VE Team brainstormed ways to improve value in the project, generating **60** creative ideas. As a result of the Evaluation Phase, **19** ideas were considered to have potential for cost savings and/or value improvement. These ideas were developed further by the VE Team and resulted in **9** VE Proposals and **10** Design Comments for consideration by CDOT going forward.

## 4.2 Organization of VE Proposals and Design Comments

This section contains the complete documentation of all VE Proposals and Design Comments that have resulted from the VE Study. The ideas from which the VE Proposals and Design Comments began are provided. The complete list of creative ideas and their evaluation is provided in the Summary of Creative Ideas and Evaluation Table provided in **Appendix C** of this report.

Each VE Proposal is documented by a separate write-up that includes:

- a description of both the original design and proposed change
- a list of advantages and disadvantages
- sketches, where appropriate
- calculations
- cost estimate for both the original design and proposed change

Each Design Comment is documented by a separate write-up that includes:

- a description of both the original design and proposed change
- a list of advantages and disadvantages
- sketches, where appropriate

Value Engineering Studies are working sessions for the purpose of developing and proposing alternative ideas for the project. As such, the results and the VE Proposals and Design Comments were developed with the resources available and within the timeframe of the 4-day workshop and are based on the information provided to the VE Team at the time of the workshop. The VE Proposals are conceptual in nature and are not intended as final design. Detailed feasibility and final design development of any VE Proposals and Design Comments, should they be accepted, remain the responsibility of CDOT. VE Team members will not sign or seal any VE Proposals and Design Comments contained in this report as certifiable engineering or architectural design.

The cost estimates for the VE Proposals were developed consistent to the cost estimate parameters used in the CDOT Preliminary Detail Cost Estimate provided to the VE Team. Based on discussions with CDOT staff, a 30% mark-up (5.5% for mobilization, 5% for MCR and 18.66% for Construction Engineering for a total of 29.16%, which was rounded up to 30%.), was used. The cost estimates prepared for this VE Study were developed solely for comparing the costs of VE Proposals to the functional equivalent in the CDOT Preliminary Detail Cost Estimate. The VE Team has limited time and resources to prepare cost estimates for each VE Proposal. Therefore, these cost estimates are not recommended to be used for budgeting or construction purposes.

CDOT should more accurately quantify any savings/additional costs resulting from acceptance of the VE Proposals.

## 4.3 Acceptance of VE Proposals and Design Comments

This report includes VE Proposals and Design Comments that could enhance the value of this project. These VE Proposals and Design Comments should be evaluated individually as they require additional design, cost estimating and/or evaluation prior to implementation. Consideration should be given to the areas within a VE Proposal and Design Comment that are acceptable and implement those parts only. Any VE Proposal and Design Comment can be accepted in whole or in part.

The VE Proposals and Design Comments were developed based on the information provided to the VE Team prior to and during the workshop. As the design proceeds, new information may become available and this information should be evaluated for potential impacts to the VE Proposals and Design Comments.

## 4.4 VE Proposals

The **9** VE Proposals developed by the VE Team are presented in this section. They are listed in the order in which they are provided in **Table 2**. The cost estimates for the VE Proposals were developed consistent to the cost estimate parameters used in the CDOT Preliminary Detail Cost Estimate provided to the VE Team.

The VE Proposals and Design Comments are conceptual in nature and are not intended as final designs. Feasibility and final design development of any VE Proposals should they be accepted, remain the responsibility of CDOT as detailed feasibility of the VE Proposals could not be undertaken at the time of the VE Study due to technical and time limitations. Discussions with respect to the viability of the VE Proposals will need to be undertaken by CDOT with the project stakeholders.

| VE PROPOSAL VE-1 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 1**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Accelerate Schedule** | **Page No.: 1 of 2** |

VE-1: Idea 1: Accelerate Schedule

ORIGINAL DESIGN:
The construction schedule for this project would be calculated based on previous interstate 70 projects with similar bid items. The I-70 Genoa project is 11.3 miles in length. The contractor averages 1 mile per 20 working days (working day = 10-hr). The project would then take 226 working days to complete. The current CDOT specifications do not allow work on weekends, nights, or holidays unless approved by the Engineer. The typical working days for one month are 21 days. With the 21 working days/month this project would take 10.8 months to complete. A construction season for an interstate project is from March 15th to October 31st (7.5 months). That would mean that the project would need to utilize two construction seasons to be completed.

PROPOSED DESIGN:
The proposed design is to accelerate the construction schedule so that the project is completed in one construction season instead of two by using incentives/disincentives and a must finish before date specification. This means that CDOT would allow the contractor to work weekends to accelerate their schedule.

ADVANTAGES:
- Reduces the length of the construction schedule
- Reduces the time that the traveling public is impacted by the project
- Allows the contractor to work on another project for the next construction season
- Less maintenance during the construction phase on the head to head traffic side
- Less exposure of the construction staff to the traveling public

DISADVANTAGES:
- Increases cost to the construction project
- Hard to get enough staff for the contractor's laborers and truck drivers
- Working approximately 72 hours per week can cause lower quality due to tired workers
- Increase in potential for claims

DISCUSSION/JUSTIFICATION:
The advantage of accelerating the project schedule is that it would allow the project to be completed in one construction season instead of two. To construct full width concrete paving in one direction of the interstate, the traffic must be moved to the opposite side of the interstate and put into a head to head configuration. By accelerating the project schedule and completing all items in one construction season it would cut off 3.3 months of the head to head configuration for the traveling public on the interstate. It would also allow the Contractor and construction staff to work on another project during the second construction season.

| VE PROPOSAL VE-1 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 1**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Accelerate Schedule** | **Page No.: 2 of 2** |

| | Construction Costs |
|---|---|
| Base Case Design | - |
| Proposed Design | $2,530,707 |
| **Estimated Additional Costs** | **$2,530,707** |

DISCUSSION OF RISK IMPACTS:

The largest risk for accelerating the project schedule is having a contractor that can provide the staffing and truck drivers to put in the longer hours and work weeks. There is a federal requirement to have traffic out of head to head configuration on Interstate 70 by November 1. This poses another potential risk of the contractor failing to meet the accelerated schedule, thus having traffic in the head to head configuration past the November 1 deadline. FHWA and CDOT do not want head to head traffic on the interstate after October 31st due to the chances of snow and bad weather which could increases risk of severe accidents.

ASSUMPTIONS AND CALCULATIONS:

It is our understanding that the labor rates on transportation projects are dependent upon a number of factors including location, type of project etc. Therefore, the labor rates for transportation projects have been found to vary between 20 and 50 percent. Using this information, the average of 35% was used.

| | hours/day | day/month | hr/month | Total HR to complete project | Total months to complete project | overtime hr/week |
|---|---|---|---|---|---|---|
| Original Design | 10 | 21 | 210 | 2260 | 10.8 | 10 |
| Proposed Design | 12 | 25 | 300 | 2260 | 7.5 | 32 |

226 days @10 hr/day = 2,260 hours

| | |
|---|---|
| Additional overtime/week | 22 |
| Additional overtime/month | 88 |
| Additional overtime for proposal | 663 |

Time and a half extra hours

331.47

Additional cost for overtime

**$2,530,707.14**

| Total construction | 35% = Labor of total cost | Total HR to complete | dollar/hr for entire labor cost |
|---|---|---|---|
| $49,299,489.83 | $17,254,821.44 | 2,260 | $7,634.88 |

| VE PROPOSAL VE-2 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 3**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Re-evaluate the concrete design** | **Page No.: 1 of 5** |

VE-2: Idea 3: Re-evaluate the concrete design

ORIGINAL DESIGN:
The current design shows Class-P PCCP being installed, per specifications. Concrete overlay thickness of 9.5" was recommended along with 11" in the reconstruction locations in order to improve vertical clearance for structures.

PROPOSED DESIGN:
Based on CDOT's 2020 Pavement Design Manual, the VE Team re-evaluated the pavement design and 8.5" of PCCP will meet the minimum requirements for the overlay areas and 10" is recommended for the reconstructed locations where the existing pavement is removed.

ADVANTAGES:
- Potential to reduce costs
- Potential to accelerate schedule
- Potential to minimize elevation gain

DISADVANTAGES:
- Potential to reduce service life due to an increase in transverse cracking
- Redesign required
- Potential to increase future maintenance cost

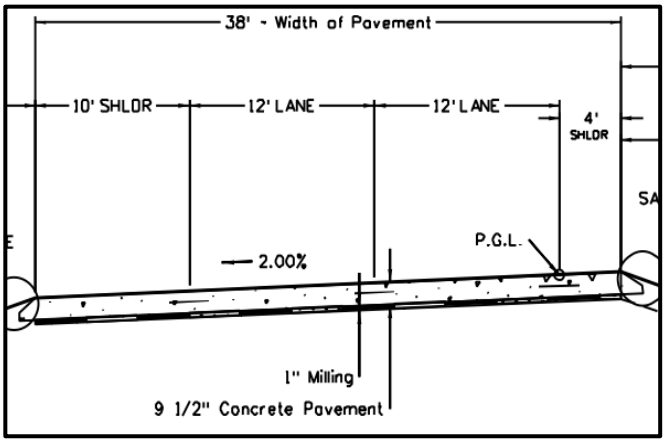
DISCUSSION/JUSTIFICATION:
The baseline concept shows Class-P PCCP being installed, per specifications, at thicknesses of 9.5" and 11" used at various locations throughout the project. Thinner sections of concrete could accelerate the Contractor's schedule and minimize the elevation gain of the roadway profile.

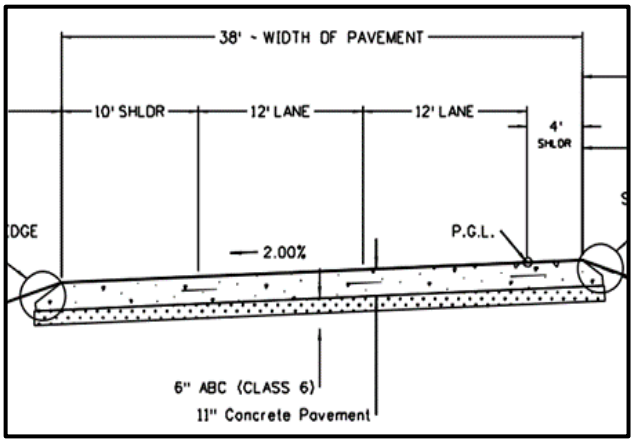
DISCUSSION OF RISK IMPACTS:
The proposed design has the potential to increase the amount of transverse cracking thus reducing service life compared to the base case design. However, the proposed design meets the 27-year distress threshold as per CDOT 2020 Pavement Design Manual. It would also require time and costs to redesign what is currently shown in the plans.

| | **Construction Costs** |
|---|---|
| Base Case Design | $31,995,525 |
| Proposed Design | $28,527,560 |
| **Estimated Cost Saving** | **$3,467,965** |

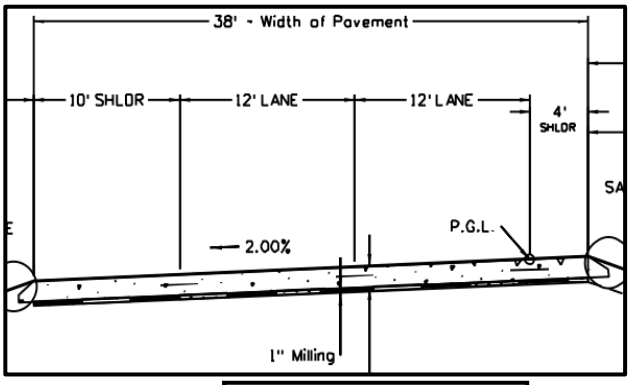
| VE PROPOSAL VE-2 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 3**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Re-evaluate the concrete design** | **Page No.: 2 of 5** |

ORIGINAL DESIGN SKETCH:

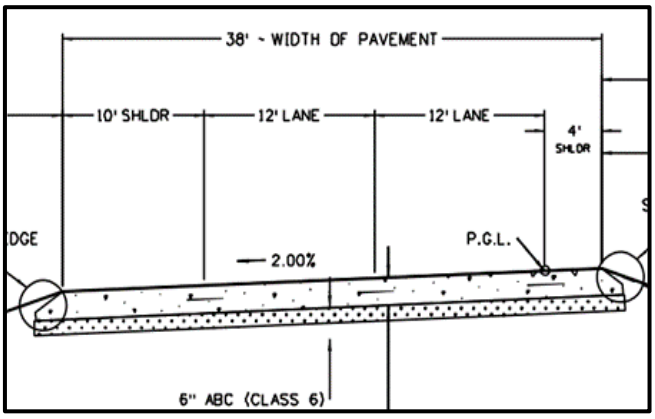



PROPOSED CHANGE SKETCH:




8 1/2" Concrete




6"ABC and 10" Concrete Pavement

At westbound structure G-23-AM

| VE PROPOSAL VE-2 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 3**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Re-evaluate the concrete design** | **Page No.: 3 of 5** |

ORIGINAL DESIGN - OVERLAY AEA:

## JPCP_over_AC_Genoa Project(650 psi)

File Name: C:\Users\goldbaum\Desktop\Genoa Project\JPCP_over_AC_Genoa Project(650 psi).dgpx

### Design Inputs

Design Life: 30 years
Design Type: JPCP_ACC

Existing construction: May, 2006
Pavement construction: July, 2021
Traffic opening: October, 2021

Climate Data Sources (Lat/Lon): 39.217, -104.633

#### Design Structure

| Layer type | Material Type | Thickness (in) |
|---|---|---|
| PCC | R4 Level 3 Flex Lawson | 8.5 |
| Flexible (existing) | Default asphalt concrete | 8.0 |
| Subgrade | A-1-a | 6.0 |
| Subgrade | A-7-6 | 36.0 |
| Subgrade | A-6 | Semi-infinite |

| Joint Design: | |
|---|---|
| Joint spacing (ft) | 15.0 |
| Dowel diameter (in) | 1.25 |
| Slab width (ft) | 12.0 |

#### Traffic

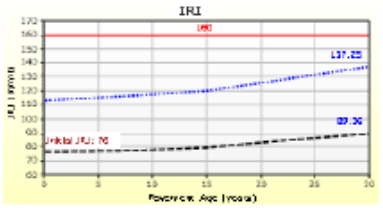
| Age (year) | Heavy Trucks (cumulative) |
|---|---|
| 2021 (initial) | 3,501 |
| 2036 (15 years) | 9,395,640 |
| 2051 (30 years) | 20,632,200 |

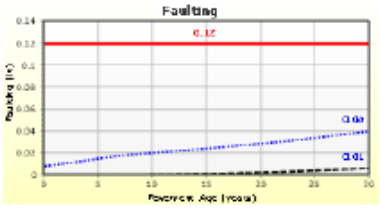
### Design Outputs

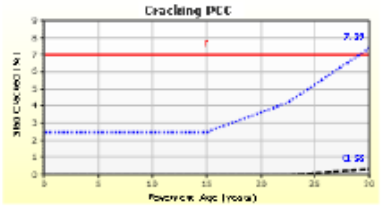
#### Distress Prediction Summary

| Distress Type | Distress @ Specified Reliability | | Reliability (%) | | Criterion Satisfied? |
|---|---|---|---|---|---|
| | Target | Predicted | Target | Achieved | |
| Terminal IRI (in/mile) | 160.00 | 137.25 | 95.00 | 99.24 | Pass |
| Mean joint faulting (in) | 0.12 | 0.04 | 95.00 | 100.00 | Pass |
| JPCP transverse cracking (percent slabs) | 7.00 | 7.39 | 95.00 | 93.99 | Fail |

#### Distress Charts



| VE PROPOSAL VE-2 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 3**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Re-evaluate the concrete design** | **Page No.: 4 of 5** |

PROPOSED CHANGE - NEW CONSTRUCTION AREA:

## New JPCP_at Structure G-23-AM

File Name: C:\Users\goldbaum\Desktop\Genoa Project\New JPCP_at Structure G-23-AM.dgpx

### Design Inputs

Design Life: 30 years
Design Type: JPCP

Existing construction: -
Pavement construction: July, 2021
Traffic opening: October, 2021

Climate Data Sources (Lat/Lon): 39.217, -104.633

#### Design Structure

| Layer type | Material Type | Thickness (in) |
|---|---|---|
| PCC | R4 Level 3 Flex Lawson | 10.0 |
| NonStabilized | Crushed gravel | 6.0 |
| Subgrade | A-2-4 R-Value 40 | 10.0 |
| Subgrade | A-7-6 | Semi-infinite |

| Joint Design: | |
|---|---|
| Joint spacing (ft) | 15.0 |
| Dowel diameter (in) | 1.50 |
| Slab width (ft) | 12.0 |

#### Traffic

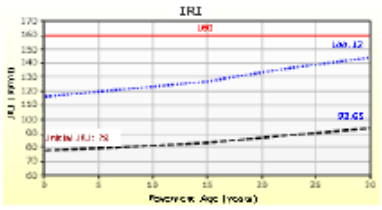
| Age (year) | Heavy Trucks (cumulative) |
|---|---|
| 2021 (initial) | 3,501 |
| 2036 (15 years) | 9,395,640 |
| 2051 (30 years) | 20,632,200 |

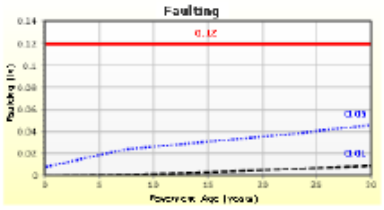
### Design Outputs

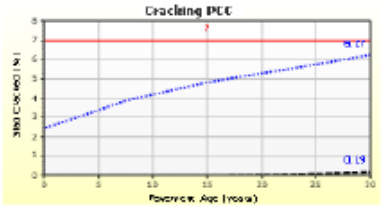
#### Distress Prediction Summary

| Distress Type | Distress @ Specified Reliability | | Reliability (%) | | Criterion Satisfied? |
|---|---|---|---|---|---|
| | Target | Predicted | Target | Achieved | |
| Terminal IRI (in/mile) | 160.00 | 144.12 | 95.00 | 98.47 | Pass |
| Mean joint faulting (in) | 0.12 | 0.05 | 95.00 | 100.00 | Pass |
| JPCP transverse cracking (percent slabs) | 7.00 | 6.27 | 95.00 | 96.73 | Pass |

#### Distress Charts



| VE PROPOSAL VE-2 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 3**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Re-evaluate the concrete design** | **Page No.: 5 of 5** |

ASSUMPTIONS AND CALCULATIONS:
Using a total paving quantity of 505,000 square yards for this project. The milling quantity would be the same for both options. Used the preliminary cost estimate developed for this project. Anticipate that 1,000 feet will be reconstructed at each structure in the East and West bound direction.

9.5-inch PCCP = $48.00/Yd$^2$ = $5.05/Yd$^2$Inch (48/9.5)
11-inch PCCP = $65.00/Yd$^2$ = $5.91/Yd$^2$ Inch (65/11)

8.5-inch PCCP = $43.00*provided by CDOT Cost Estimating 7/16/19
10-inch PCCP = $49.50*provided by CDOT Cost Estimating 7/16/19
10” PCCP = 32,182 SY
8.5” PCCP = 469,169 SY

| Construction Item | | Current Design | | | Proposed Design | | |
|---|---|---|---|---|---|---|---|
| **Item** | **Units** | **Qty** | **Unit $** | **Total** | **Qty** | **Unit $** | **Total** |
| 412-00950 Concrete Pavement (9.5”) | Yd² | 469,169 | $48 | $22,520,112 | | | |
| 412-00110 Concrete Pavement (11”) | Yd² | 32,182 | $65 | $2,091,830 | | | |
| 412-00100 Concrete Pavement (10”) | Yd² | | | | 32,182 | $55 | $1,770,010 |
| 412-00850 Concrete Pavement (8.5”) | Yd² | | | | 469,169 | $43 | $20,174,267 |
| **Subtotal** | | | | $24,611,942 | | | $21,944,277 |
| **Mark-up** | 30% | | | 1.30 | | | 1.30 |
| **Total** | | | | **$31,995,525** | | | **$28,527,560** |
| | | | | | | **Net Cost Avoidance** | **$3,467,965** |

| VE PROPOSAL VE-3 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 4**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Optimize milling** | **Page No.: 1 of 3** |

VE-3: Idea 4: Optimize milling

ORIGINAL DESIGN:
The current design shows 1" milling across the full width of the pavement to roughen up the HMA surface to create a bond with the fresh concrete.

PROPOSED DESIGN:
During our site visit on July 9th, the VE Team noticed some locations where the cross-slope seemed to be at 0.015. Other locations had multiple thin overlays; however, they were only in the driving lanes. It is recommended to mill the cross-slope to the 0.020 specification by feathering the milling from zero inches at the control point to a minimum required depth to develop a 0.020 cross-slope.

ADVANTAGES:
- Potential to reduce costs
- Potential to minimize elevation gain

DISADVANTAGES:
- May delay the project in order to get a more accurate survey
- May require additional cores in the shoulder locations to determine existing thickness of HMA
- Milling at the shoulder location would require an additional 1.25 inches above the original design

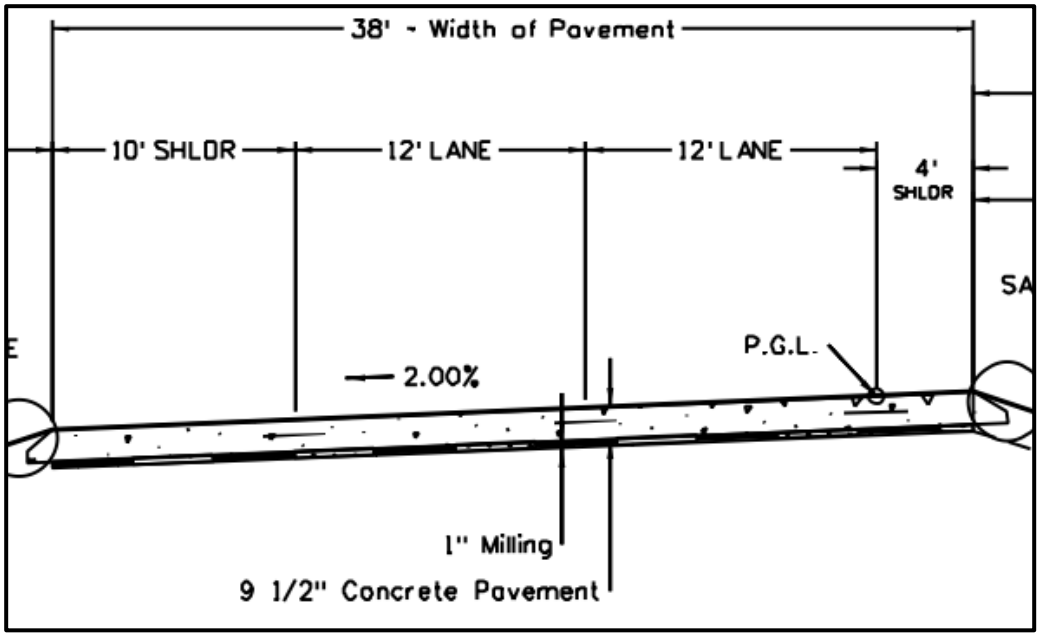
DISCUSSION/JUSTIFICATION:
Based on the current thickness of the HMA, milling the cross-slope will not impact the minimum HMA thickness needed to support the PCCP. Only milling required sections of the existing HMA could accelerate the Contractor's schedule and minimize the Contractor's risk of placing additional concrete to meet the required cross-slope. The current HMA surface will provide an adequate bond due to the age of the HMA.

DISCUSSION OF RISK IMPACTS:
Accurately surveying the current cross-slope has a potential to delay the delivery of the project. However, funding for this project has not been allocated. It would require time and increase the cost to redesign what is currently shown in the plans. The additional depth of milling in the shoulder locations may increase the possibility of unstable subgrade.

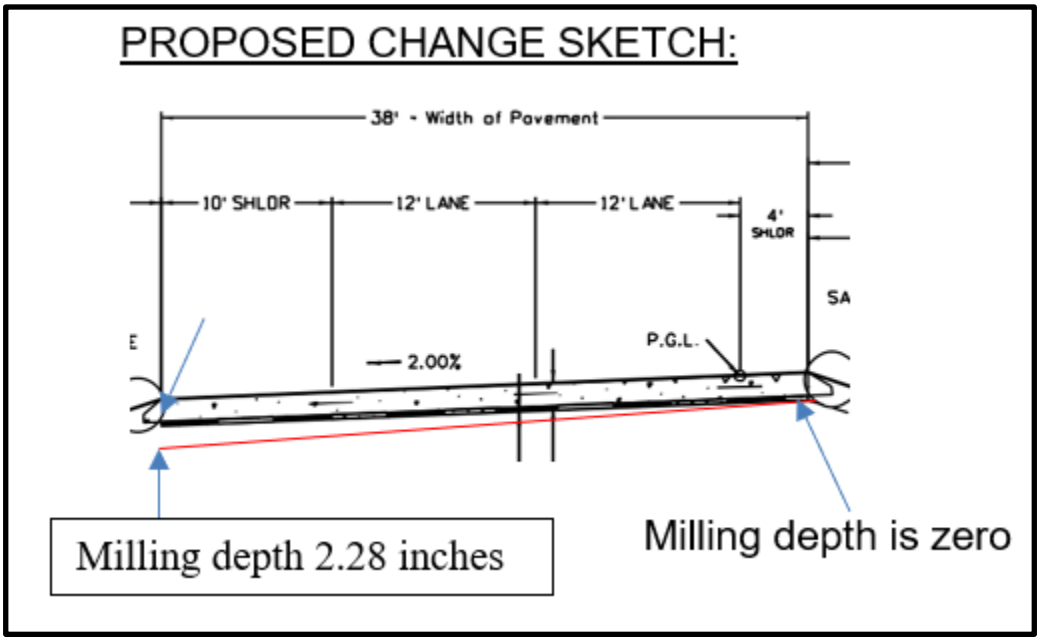
| | **Construction Costs** |
|---|---|
| Base Case Design | $4,336,597 |
| Proposed Design | $3,716,131 |
| **Estimated Cost Saving** | **$620,466** |

| VE PROPOSAL VE-3 | |
|---|---|
| **PROJECT:** 22463 I-70 Genoa Pavement Reconstruction Project | **Idea No.: 4**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Optimize milling** | **Page No.: 2 of 3** |

ORIGINAL DESIGN SKETCH:




PROPOSED CHANGE SKETCH:



| VE PROPOSAL VE-3 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 4**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Optimize milling** | **Page No.: 3 of 3** |

ASSUMPTIONS AND CALCULATIONS:

Estimating that 80 percent of the project is at a cross-slope of 0.015. It is assumed that the contractor will correct the cross-slope in PCCP. It is estimated that 10,000 cubic yards of furnished concrete pavement will be needed to fill unstable locations created by the Contractor's equipment driving over the milled surface. It is estimated that the cost of milling the surface will increase due to the control needed to mill the surface to the specified cross-slope.

Area of milling = 501,351 $yd^2$ x 0.80 = 401,081 $yd^2$

Depth of milling = 0.020 – 0.015 = 0.005 x 38' wide = 0.19' x 12 inches = 2.28 inches

Area of milling = 0.5 x (38' x (2.28/12)) = 3.61 $ft^2$ / 9 = 0.4011 $yd^2$

Volume of concrete furnished by the contractor needed to adjust cross-slope = 0.4011 $yd^2$ x (0.80 x 11.3 miles x 5280 feet x 2 directions / 3) = 12,763 $yd^3$ x 1.10 for irregularities in the surface = 14,040 $yd^3$

Based on the estimated unit cost of \$48.00/ $yd^2$ for 9.5" PCCP the furnished concrete cost is 9.5 inches / 36 inches = 0.2639 yards thick. Therefore, \$48.00/0.2639 = \$181.89 / $yd^3$

| **Construction Item** | | **Current Design** | | | **Proposed Design** | | |
|---|---|---|---|---|---|---|---|
| **Item** | **Units** | **Qty** | **Unit \$** | **Total** | **Qty** | **Unit \$** | **Total** |
| 202-00240 removal of asphalt mat (Planing) | $Yd^2$ | 501,351 | \$1.56 | \$782,108 | 401,081 | \$2.00 | \$802,162 |
| 412-00000 Furnish Concrete Pavement | CY | 14,040 | \$181.89 | \$2,553,736 | 10,000 | \$181.89 | \$1,818,900 |
| 625-00001 Construction Surveying (Hourly) | Hr | | | \$0 | 500 | \$150 | \$75,000 |
| Traffic Control | Day | | | \$0 | 65 | \$2,500 | \$162,500 |
| **Subtotal** | | | | \$3,335,844 | | | \$2,858,562 |
| **Mark-up** | 30% | | | 1.30 | | | 1.30 |
| **Total** | | | | **\$4,336,597** | | | **\$3,716,131** |
| | | | | | | **Net Cost Avoidance** | **\$620,466** |

| VE PROPOSAL VE-4 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 12**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Use widened lanes** | **Page No.: 1 of 4** |

VE-4: Idea 12: Use widened lanes

ORIGINAL DESIGN:
Original design is based on 12' concrete slab width and 33 dowel bars per transverse joint. Concrete overlay thickness of 9.5" was recommended along with 11" in the reconstruction locations in order to improve vertical clearance for structures.

PROPOSED DESIGN:
Along with the optimized designs in Idea 3, the proposed slab width of 13' is recommended in Lane 2 where the longitudinal joint foot falls in the outside shoulder and one foot away from the white stripe.

ADVANTAGES:
- Reduce concrete thickness by 1 1/4 inch from the base design of 9.5 inches
- Reduces costs
- Reduces distresses at the sawcut
- Edge of the pavement is further away from the wheel path

DISADVANTAGES:
- The travelling public uses the longitudinal joint as a guide when they can't see the white stripe
- Increases the number of dowel bars
- May be prone to early cracking if not constructed with care and reinforcement not placed properly

DISCUSSION/JUSTIFICATION:
The widen lane is a current CDOT design standard. Widened slabs have been used to mitigate transverse cracking in Jointed Plane Concrete Pavement (JPCP) because edge load compared to interior and corner loads usually produces the highest stress on Jointed Plane Concrete Pavement. By using widened slabs, load is not applied to slab edges, so the transverse cracking potential is diminished. Finite element models have shown that stress is highest at the longitudinal joint nearest to the free edge. Therefore, the longitudinal joint nearest to the outside shoulder becomes the critical joint. In 1994, a study was conducted on Interstate 70 in Colorado near the Colorado-Kansas border to examine the effects of tied PCC shoulder and widened slabs (14-foot slabs). The results indicated that the measured strains dropped significantly in the 14-foot wide lane as compared to the 12-foot wide lane. CDOT started using the 14-foot wide slabs in 1995 on I-70 from milepost 348.2 to milepost 358.1.

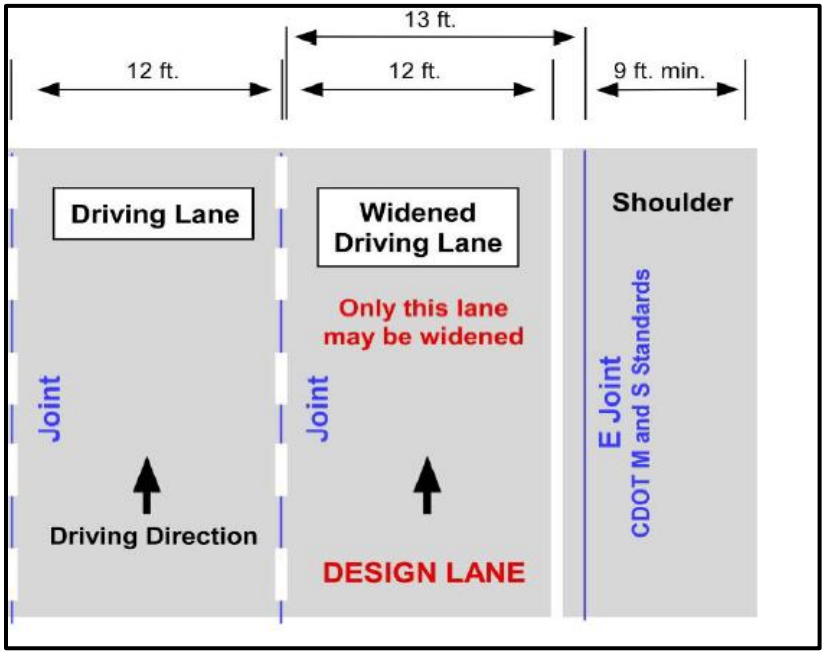
When the VE Team analyzed previous projects on I-70, it was shown that the overall average of low severity longitudinal cracking is about 60 percent less in the widen lane as compared to the 12-foot lane while the average total longitudinal cracking in the widen lane is about 10 percent less than the 12-foot lane.

| VE PROPOSAL VE-4 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 12**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Use widened lanes** | **Page No.: 2 of 4** |

DISCUSSION OF RISK IMPACTS:
The shoulder would need to be removed and replaced if the current shoulder becomes a future driving lane.

| | Construction Costs |
|---|---|
| Base Case Design | $31,995,525 |
| Proposed Design | $28,690,500 |
| **Estimated Cost Saving** | **$3,305,025** |

PROPOSED CHANGE SKETCH:



| VE PROPOSAL VE-4 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 12**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Use widened lanes** | **Page No.: 3 of 4** |

Widen Lanes Analysis

## JPCP_over_AC_Genoa Project (wide slabs)(650 psi)

File Name: C:\Users\goldbaum\Desktop\Genoa Project\JPCP_over_AC_Genoa Project (wide slabs)(650 psi).dgpx

### Design Inputs

Design Life: 30 years
Design Type: JPCP_ACC

Existing construction: May, 2006
Pavement construction: July, 2021
Traffic opening: October, 2021

Climate Data Sources (Lat/Lon): 39.217, -104.633

#### Design Structure

| Layer type | Material Type | Thickness (in) |
|---|---|---|
| PCC | R4 Level 3 Flex Lawson | 8.3 |
| Flexible (existing) | Default asphalt concrete | 8.0 |
| Subgrade | A-1-a | 6.0 |
| Subgrade | A-7-6 | 36.0 |
| Subgrade | A-6 | Semi-infinite |

| Joint Design: | |
|---|---|
| Joint spacing (ft) | 15.0 |
| Dowel diameter (in) | 1.25 |
| Slab width (ft) | 13.0 (w) |

#### Traffic

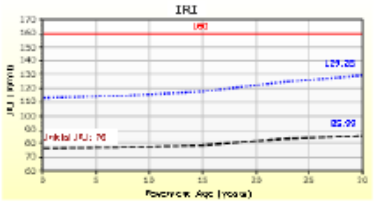
| Age (year) | Heavy Trucks (cumulative) |
|---|---|
| 2021 (initial) | 3,501 |
| 2036 (15 years) | 9,395,640 |
| 2051 (30 years) | 20,632,200 |

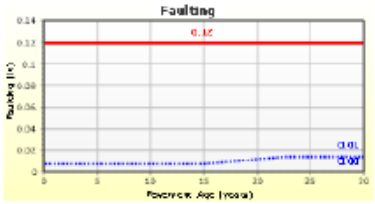
### Design Outputs

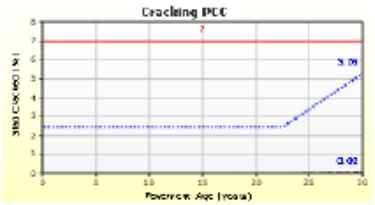
#### Distress Prediction Summary

| Distress Type | Distress @ Specified Reliability | | Reliability (%) | | Criterion Satisfied? |
|---|---|---|---|---|---|
| | Target | Predicted | Target | Achieved | |
| Terminal IRI (in/mile) | 160.00 | 129.28 | 95.00 | 99.75 | Pass |
| Mean joint faulting (in) | 0.12 | 0.01 | 95.00 | 100.00 | Pass |
| JPCP transverse cracking (percent slabs) | 7.00 | 5.26 | 95.00 | 98.60 | Pass |

#### Distress Charts



| VE PROPOSAL VE-4 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 12**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Use widened lanes** | **Page No.: 4 of 4** |

ASSUMPTIONS AND CALCULATIONS:
Using a total paving quantity of 501,351 square yards for this project. The milling quantity would be the same for both options. Used the preliminary cost estimate developed for this project. Assuming that 8.25-inch PCCP will cost the same as 8.5-inch PCCP. Assuming that 9.75-inch PCCP will cost the same as 10-inch PCCP.

9.5-inch PCCP = $48.00/Yd$^2$
11-inch PCCP = $65.00/Yd$^2$
8.5-inch PCCP = $43.00 *provided by CDOT Cost Estimating 7/22/19
10-inch PCCP = $55.00 *provided by CDOT Cost Estimating 7/22/19

One additional dowel bar at a cost $5.00 per bar. The original cost for a 15-foot panel by 12 feet wide (20 square yards) was $960 per panel for 9.5-inch-thick pavement and $1,300 for 11-inch-thick pavement with 33 bars per panel. Since one bar was added, this cost increased to $965 per panel or $48.25 per square yard for the 9.5-inch-thick pavement and $65.25 per square yard for the 11-inch-thick pavement. However, the design thickness was reduced to 8.25 inches and 9.75 inches to meet the optimized design with one additional dowel bar. The unit cost is $43.25/Yd$^2$ for 8.5-inch PCCP and $55.25/Yd$^2$ for 10-inch PCCP.

| Construction Item | | Current Design | | | Proposed Design | | |
|---|---|---|---|---|---|---|---|
| **Item** | **Units** | **Qty** | **Unit $** | **Total** | **Qty** | **Unit $** | **Total** |
| 412-00950 Concrete Pavement (9.5") | Yd² | 469,169 | $48.00 | $22,520,112 | | | |
| 412-00110 Concrete Pavement (11") | Yd² | 32,182 | $65.00 | $2,091,830 | | | |
| 412-00100 Concrete Pavement (9.75") | Yd² | | | | 32,182 | $55.25 | $1,778,056 |
| 412-00850 Concrete Pavement (8.25") | Yd² | | | | 469,169 | $43.25 | $20,291,559 |
| **Subtotal** | | | | $24,611,942 | | | $22,069,615 |
| **Mark-up** | 30% | | | 1.30 | | | 1.30 |
| **Total** | | | | **$31,995,525** | | | $28,690,499 |
| | | | | | | **Net Cost Avoidance** | **$3,305,025** |

Additional cost savings could be realized if the cost of the 8.25 and the 9.75-inch thick PCCP is less than the cost for the 8.5 and 10-inch thick PCCP.

| VE PROPOSAL VE-5 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No. 13**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Minimum vertical clearances at the bridges** | **Page No.: 1 of 4** |

VE-5: Idea 13: Minimum vertical clearances at the bridges

ORIGINAL DESIGN:
There are four existing overpass bridges within the limits of the project each with different vertical clearances (VC) over existing I-70. The original design calls for maintaining the existing profile grade of I-70 under these bridges or lowering if necessary in order to meet the minimum VC requirement of 16' 0". Since an overlay pavement section would increase the profile grade elevation, it will be necessary to transition to a full depth reconstruction section under these bridges.

PROPOSED DESIGN:
There is excess vertical clearance at two of the four overpass bridges (Structure Nos. G-23-AF and G-23-AG). The proposed design would extend the overlay pavement section at both of these locations and would still meet the 16'-0" VC requirement. Additionally, at Structure No. G-23-AD and Structure G-23-AM, it is possible to increase the roadway milling depth at 3 of the 4 crossing locations to accommodate an overlay section to avoid the full depth reconstruction.

ADVANTAGES:
- Reduces pavement cost
- Reduces construction time
- Avoids the need to expose the unstable subbase

DISADVANTAGES:
- May not provide excess vertical clearance but still meets the required standard

DISCUSSION/JUSTIFICATION:
A pavement overlay is more cost effective than full depth reconstruction. It is also easier and quicker to construct. In addition, full depth reconstruction requires that the existing pavement structure be removed entirely which opens up the subgrade material and introduces a variety of potential construction issues and delays. The spreadsheet below summarizes the existing vertical clearances at the four bridge locations and demonstrates that it is possible to utilize a pavement overlay section and still maintain 16' 0" VC at 7 of the 8 crossing locations.

DISCUSSION OF RISK IMPACTS:
This should reduce risk by eliminating the need to expose the subgrade at these 7 locations.

| VE PROPOSAL VE-5 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No. 13**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Minimum vertical clearances at the bridges** | **Page No.: 2 of 4** |

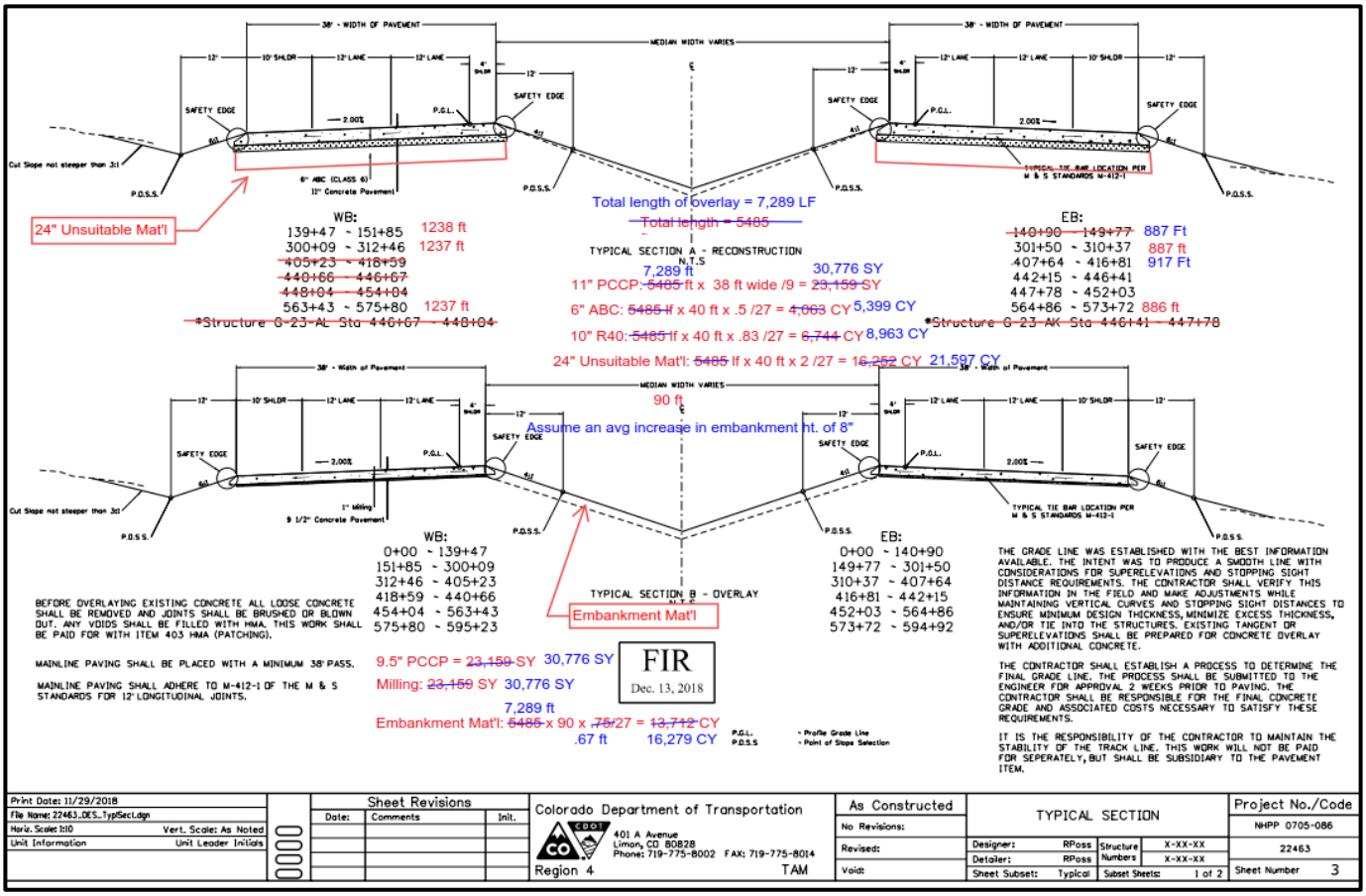
| Structure No. | Direction | Existing Vertical Clearance | Existing HMA Thickness | Proposed Pavement Treatment | Net Profile Change | Resulting Vertical Clearance |
|---|---|---|---|---|---|---|
| G-23-AD | EB | 16' 3" | 10" - 15" | 9.5" PCCP OVERLAY/ 6.5" MILLING | +3" | 16' 0" |
| | WB | 16 9" | 6.75" - 9.25" | 9.5" PCCP OVERLAY/ 1" MILLING | +8.5" | 16' 0.5" |
| G-23-AF | EB | 19' 11" | 12.25" - 16" | 9.5" PCCP OVERLAY/ 1" MILLING | +8.5" | 19' 2.5" |
| | WB | 21' 11" | 12.75" - 14" | 9.5" PCCP OVERLAY/ 1" MILLING | +8.5" | 21' 2.5" |
| G-23-AM | EB | 16' 6" | 12" | 9.5" PCCP OVERLAY/ 3.5" MILLING | +6" | 16 6" |
| | WB | 16' 1" | 13" | 11" PCCP/6"ABC/10" R40 | 0" | 16' 1" |
| G-23-AG | EB | 18' 8" | 15" - 16" | 9.5" PCCP OVERLAY/ 1" MILLING | +8.5" | 17' 10.5" |
| | WB | 21' 7" | 12" - 13" | 9.5" PCCP OVERLAY/ 1" MILLING | +8.5" | 20' 9.5" |

Cannot overlay - Full Depth Reconstruction Required

| | Construction Costs |
|---|---|
| Base Case Design | $3,937,803 |
| Proposed Design | $2,332,093 |
| **Estimated Cost Saving** | **$1,605,710** |

| VE PROPOSAL VE-5 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No. 13**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Minimum vertical clearances at the bridges** | **Page No.: 3 of 4** |

PROPOSED CHANGE SKETCH:




ASSUMPTIONS AND CALCULATIONS:

Unit costs are based upon 22463 I-70 Genoa FIR cost estimate and 21878 Arriba Bid tabs

## VE PROPOSAL VE-5

| | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No. 13**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Minimum vertical clearances at the bridges** | **Page No.: 4 of 4** |

| Construction Item | | Current Design | | | Proposed Design | | |
|---|---|---|---|---|---|---|---|
| **Item** | **Units** | **Qty** | **Unit $** | **Total** | **Qty** | **Unit $** | **Total** |
| 202 Unsuitable Material | CY | 21,957 | $25 | $548,925 | | | |
| 202 Embankment Material (R40) | CY | 8,963 | $20 | $179,260 | | | |
| 202 Embankment Material (CIP) | CY | | | | 16,279 | $10 | $162,790 |
| 203 Removal of Asphalt Mat (Planing - Special) | CY | | | | 30,776 | $5 | $153,880 |
| 304 ABC Cl. 6 | CY | 5,399 | $55.65 | $300,454 | | | |
| 410 Concrete Pavement (9.5 Inch) | SY | | | | 30,776 | $48 | $1,477,248 |
| 410 Concrete Pavement (11 Inch) | SY | 30,776 | $65 | $2,000,440 | | | |
| **Subtotal** | | | | $3,029,079 | | | $1,793,918 |
| **Mark-up** | 30% | | | 1.30 | | | 1.30 |
| **Total** | | | | **$3,937,803** | | | **$2,332,093** |
| | | | | | | **Net Cost Avoidance** | **$1,605,710** |

| VE PROPOSAL VE-6 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 17**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Use high strength concrete** | **Page No.: 1 of 3** |

VE-6: Idea 17: Use high strength concrete

ORIGINAL DESIGN:
Original design is based on 9.5 inches overlay with a 28-day flexural strength of 650 psi.

PROPOSED DESIGN:
Proposed 8.25 inches overlay with a 28-day flexural strength of 750 psi.

ADVANTAGES:
- Reduce thickness by 1.25 inches
- Reduces costs

DISADVANTAGES:
- Will require a higher level of Process Control monitoring and testing by the Contractor

DISCUSSION/JUSTIFICATION:
Most Class P concrete can meet the higher flexural strength with no adjustments to their current mix designs.

DISCUSSION OF RISK IMPACTS:
Achieving this target flexural strength may affect the Contractor's quality level and may impact the incentive/disincentive for flexural strength. If this requirement were to be implemented by CDOT, the Contractors would need time to evaluate their current quality levels for each mix design and make the appropriate modifications. The specifications for the laboratory mix design would need to be modified. The incentive/disincentive program would need to be modified as well as project specifications.

| | **Construction Costs** |
|---|---|
| Base Case Design | $29,276,146 |
| Proposed Design | $26,278,547 |
| **Estimated Cost Saving** | **$2,997,599** |

| VE PROPOSAL VE-6 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 17**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Use high strength concrete** | **Page No.: 2 of 3** |

Flexural Strength of 750 psi. analysis

## JPCP_over_AC_Genoa Project (750)

File Name: C:\Users\goldbaum\Desktop\Genoa Project\JPCP_over_AC_Genoa Project (750).dgpx

### Design Inputs

Design Life: 30 years
Design Type: JPCP_ACC

Existing construction: May, 2006
Pavement construction: July, 2021
Traffic opening: October, 2021

Climate Data Sources (Lat/Lon): 39.217, -104.633

#### Design Structure

| Layer type | Material Type | Thickness (in) |
|---|---|---|
| PCC | R4 Level 1 Lawson | 8.3 |
| Flexible (existing) | Default asphalt concrete | 8.0 |
| Subgrade | A-1-a | 6.0 |
| Subgrade | A-7-6 | 36.0 |
| Subgrade | A-6 | Semi-infinite |

| Joint Design: | |
|---|---|
| Joint spacing (ft) | 15.0 |
| Dowel diameter (in) | 1.25 |
| Slab width (ft) | 12.0 |

#### Traffic

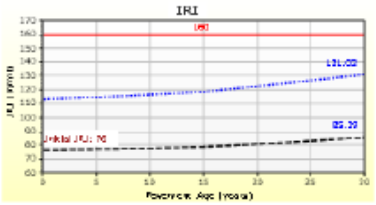
| Age (year) | Heavy Trucks (cumulative) |
|---|---|
| 2021 (initial) | 3,501 |
| 2036 (15 years) | 9,395,640 |
| 2051 (30 years) | 20,632,200 |

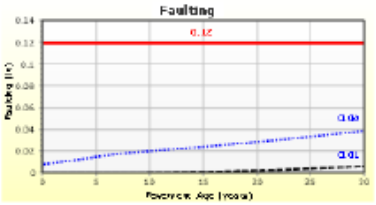
### Design Outputs

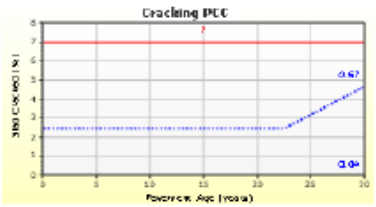
#### Distress Prediction Summary

| Distress Type | Distress @ Specified Reliability | | Reliability (%) | | Criterion Satisfied? |
|---|---|---|---|---|---|
| | Target | Predicted | Target | Achieved | |
| Terminal IRI (in/mile) | 160.00 | 131.03 | 95.00 | 99.64 | Pass |
| Mean joint faulting (in) | 0.12 | 0.04 | 95.00 | 100.00 | Pass |
| JPCP transverse cracking (percent slabs) | 7.00 | 4.67 | 95.00 | 99.33 | Pass |

#### Distress Charts



| VE PROPOSAL VE-6 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 17**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Use high strength concrete** | **Page No.: 3 of 3** |

ASSUMPTIONS AND CALCULATIONS:
Assumed no additional cementitious materials will be needed. Assumed one additional Process Control Tester will be needed to monitor the materials. Assuming the 8.25-inch PCCP will cost the same as 8.5-inch PCCP.

8.5-inch PCCP = $43.00* provided by CDOT Cost Estimating 7/16/19

| Construction Item | | Current Design | | | Proposed Design | | |
|---|---|---|---|---|---|---|---|
| **Item** | **Units** | **Qty** | **Unit $** | **Total** | **Qty** | **Unit $** | **Total** |
| 412-00950 Concrete Pavement (9.5”) | Yd² | 469,169 | $48 | $22,520,112 | | | |
| 412-00825 Concrete Pavement (8.25”) | Yd² | | | | 469,169 | $43 | $20,174,267 |
| Process Control Tester | Hour | | | | 1,600 | $25 | $40,000 |
| **Subtotal** | | | | $22,520,112 | | | $20,214,267 |
| **Mark-up** | 30% | | | 1.30 | | | 1.30 |
| **Total** | | | | **$29,276,146** | | | **$26,278,547** |
| | | | | | | **Net Cost Avoidance** | **$2,997,599** |

| VE PROPOSAL VE-7 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 23**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Use millings generated on project for subbase material** | **Page No.: 1 of 2** |

VE-7: Idea 22: Use millings generated on project for subbase material

ORIGINAL DESIGN:
The current design has millings generated from the project being hauled off of the project. The millings are not reused on the project with the current design. The current design also proposes using 10" R-40 in the reconstruction areas in the eastbound direction.

PROPOSED DESIGN:
The VE Team proposes using a portion of the millings generated on this project in place of the R-40 material in the reconstruction areas where there are vertical restrictions. There are 4 overpass areas and a set of sister bridges that are vertically restricted areas on this project.

ADVANTAGES:
- Reduces costs
- Reduces schedule
- Eliminates some trucking

DISADVANTAGES:
- Potential to trap water
- Potential compaction issues
- Potential for additional cracking in PCCP

DISCUSSION/JUSTIFICATION:
The schedule would also be reduced in that there would not need to be any R-40 material required to be trucked in and stockpiled. CDOT has used millings as subbase material on I-70 near Cedar Point and at other locations without detrimental effects. Stripping of the milling material is negligible due to the minimal amount of moisture and that PCCP tends to distribute the implied load evenly across the surface of the subbase.

DISCUSSION OF RISK IMPACTS:
Reusing a portion of the millings generated on the project in place of the R-40 material currently required for the reconstruction areas in the eastbound direction where there are vertical restrictions could have the potential to trap water. The material being milled might not produce a sufficient enough gradation to allow water to properly drain through it. The milling material might also pose the risk of not being able to reach the desired compaction. The issue of long-term creep has been a concern by some Regional Materials Engineers. Due to the sustained load on the millings, long-term creep may induce more cracking in the PCCP.

| VE PROPOSAL VE-7 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 23**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Use millings generated on project for subbase material** | **Page No.: 2 of 2** |

| ` | Construction Costs |
|---|---|
| Base Case Design | $184,566 |
| Proposed Design | $80,249 |
| **Estimated Cost Saving** | **$104,317** |

ASSUMPTIONS AND CALCULATIONS:
R-40 Material Required
10” R-40 material required in EB recon areas

EB recon areas – 1,000 LF/area * (5 areas) = 5,000 LF
5,000LF (40’ wide roadway) (10/12) = 166,666.66 CF (1/27) = 6,173 CY R-40 Material
6,173 CY ($29.90/CY) = $184,566 **this includes 30% markup
**40’ width is used as subbase material is wider than roadway width due to being placed below the safety edge

Millings Generated
1” Milling for entire length of project EB and WB direction
501,351 SY (9) (1/12) = 376,013 CF (1/27) = 13,926 CY Millings
$10/CY to stockpile and place millings
6,173 CY($13/CY) = $80,249 **this includes 30% markup
>>This is to show there are enough millings to satisfy the required 6,173 CY R-40 material

| VE PROPOSAL VE-8 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 45**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Reuse unsuitable material for shouldering** | **Page No.: 1 of 2** |

VE-8: Idea 45: Reuse unsuitable material for shouldering

ORIGINAL DESIGN:
The current project has no plans or specs for reuse of unsuitable material.

PROPOSED DESIGN:
Reuse of Unsuitable Material from excavation at reconstruction areas by the bridges and overpasses for shouldering material for the Embankment CIP.

ADVANTAGES:
- Reduces costs
- Reduces schedule
- Reduces truck traffic on the roadway

DISADVANTAGES:
- Time required for drying unsuitable material prior to installation
- High variability in material
- Potential for errant vehicles/trucks to get stuck if they venture off the paved surface

DISCUSSION/JUSTIFICATION
In prior projects, the use of Unsuitable Material (unsuitable excavation) has been allowed for Embankment CIP for shouldering. Current quantity estimate for item Embankment CIP is 89,591 CY at an estimated cost of $20.00 = $1,791,820. It estimated that the reuse of 29,630 CY of Unsuitable Material (see Assumptions & Calculations below) for Embankment CIP would result in lower Contractor bid unit prices since they would not have to pay for and haul in Embankment CIP. The current shouldering material along most CDOT highways use clay soils like this project.

203.06

(c) *Unsuitable Material*. Unsuitable materials encountered in the subgrade, roadway, or embankment foundation that are determined to be detrimental to the roadway or embankment shall be removed to the depth and extents directed by the Engineer. The excavated area shall be backfilled to the finished graded section with approved material. Materials that contain organics or that cannot be dried or moisture conditioned, then compacted to the required density shall be disposed of and shall not be reused as embankment fill. Materials that don't contain organics and that can be dried or moisture conditioned and compacted to the required density may be reused as embankment fill as approved by the Engineer.

| VE PROPOSAL VE-8 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 45**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Reuse unsuitable material for shouldering** | **Page No.: 2 of 2** |

| ` | Construction Costs |
|---|---|
| Base Case Design | $1,791,820 |
| Proposed Design | $1,347,370 |
| **Estimated Cost Saving** | **$444,450** |

DISCUSSION OF RISK IMPACTS:
There is potential for a high variability in material that could be used for the shouldering making it harder to test and reach minimum density specifications. Some vehicles may get stuck in the mud in the rainy season if they get too far off the paved shoulder. There is a potential for errant vehicles and trucks to get stuck in the soft unsuitable material if they were to drive off of the paved surface. However, this condition is not different from today's condition where vehicles could get stuck during inclement weather or wet conditions.

ASSUMPTIONS AND CALCULATIONS:
Assumed 2' deep of Unsuitable Material.
89,591 CY at an estimated cost of $20.00/CY = $1,791,820.

4 Overpasses x 1,000' x 2(both EB & WB lanes) = 8,000 LF
2 Bridges x 1,000' (One each EB & WB lanes) = 2,000 LF

8,000 LF + 2,000 LF = 10,000 LF
10,000 LF x 40' (Road width) x 2' (Thick) = 800,000 CF

800,000 CF / 27 CF/CY = 29,630 CY

Assumed reduction in price for 29,630 CY at 75% of estimated cost $20.00/CY.
$20.00 x 0.75 = $15.00 29,630 CY x $15.00 = $444,450 Estimated Savings

$1,791,820 - $444,450 = $1,347,370 (New estimated cost for Embankment CIP).

| 'VE PROPOSAL VE-9 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 54**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Reduce concrete thickness by using shorter panels** | **Page No.: 1 of 4** |

VE-9: Idea 54: Reduce concrete thickness by using shorter panels

ORIGINAL DESIGN:
The current design shows Class-P PCCP being installed, per specifications with transverse joints at 15-foot intervals.

PROPOSED DESIGN:
Based on CDOT's 2020 Pavement Design Manual, the VE Team re-evaluated the pavement design with 12-foot panel length.

ADVANTAGES:
- Potential to reduce the amount of transverse cracks
- Potential to extend service life
- Reduces the overlay thickness of concrete to 8.25" and the reconstruction concrete to 9.75"
- Reduces costs

DISADVANTAGES:
- Increases the potential for the Contractor to misplace the transverse joints
- Increases the number of transverse joints
- Increases the linear feet of sawing and sealing transverse joints
- Increases the number dowel bars
- Over time the potential for incompressible materials to fill a transverse crack and break the PCCP
- Increases maintenance efforts to clean and reseal the joints

DISCUSSION/JUSTIFICATION:
The shorter panel length will create less warping and curling in the panel. The tractor portion of a Class 9 vehicle will span the shorter length thereby implying less stress on a panel.

DISCUSSION OF RISK IMPACTS:
It would require time and costs to redesign what is currently shown in the plans. It would increase the future maintenance cost to clean and reseal the joints.

| | **Construction Costs** |
|---|---|
| Base Case Design | $31,995,525 |
| Proposed Design | $30,724,642 |
| **Estimated Cost Saving** | **$1,270,883** |

| 'VE PROPOSAL VE-9 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 54**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Reduce concrete thickness by using shorter panels** | **Page No.: 2 of 4** |

12' Long Panels

## JPCP_over_AC_Genoa Project(650 psi)(12 foot transverse)

File Name: C:\Users\goldbaum\Desktop\Genoa Project\JPCP_over_AC_Genoa Project(650 psi)(12 foot transverse).dgpx

### Design Inputs

Design Life: 30 years
Design Type: JPCP_ACC

Existing construction: May, 2006
Pavement construction: July, 2021
Traffic opening: October, 2021

Climate Data Sources (Lat/Lon): 39.217, -104.633

#### Design Structure

| Layer type | Material Type | Thickness (in) |
|---|---|---|
| PCC | R4 Level 3 Flex Lawson | 8.3 |
| Flexible (existing) | Default asphalt concrete | 8.0 |
| Subgrade | A-1-a | 6.0 |
| Subgrade | A-7-6 | 36.0 |
| Subgrade | A-6 | Semi-infinite |

| Joint Design: | |
|---|---|
| Joint spacing (ft) | 12.0 |
| Dowel diameter (in) | 1.25 |
| Slab width (ft) | 12.0 |

#### Traffic

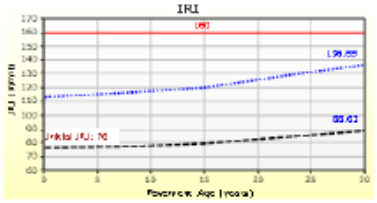
| Age (year) | Heavy Trucks (cumulative) |
|---|---|
| 2021 (initial) | 3,501 |
| 2036 (15 years) | 9,395,640 |
| 2051 (30 years) | 20,632,200 |

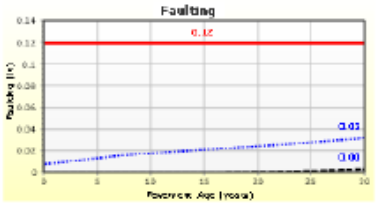
### Design Outputs

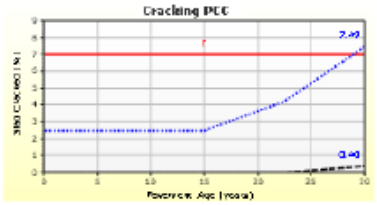
#### Distress Prediction Summary

| Distress Type | Distress @ Specified Reliability | | Reliability (%) | | Criterion Satisfied? |
|---|---|---|---|---|---|
| | Target | Predicted | Target | Achieved | |
| Terminal IRI (in/mile) | 160.00 | 136.69 | 95.00 | 99.27 | Pass |
| Mean joint faulting (in) | 0.12 | 0.03 | 95.00 | 100.00 | Pass |
| JPCP transverse cracking (percent slabs) | 7.00 | 7.49 | 95.00 | 93.73 | Fail |

#### Distress Charts



| 'VE PROPOSAL VE-9 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 54**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Reduce concrete thickness by using shorter panels** | **Page No.: 3 of 4** |

ASSUMPTIONS AND CALCULATIONS:

This design does not include the information from Idea 3. Using a total paving quantity of 501,351 square yards for this project. The milling quantity would be the same for both options. Used the preliminary cost estimate developed for this project. Assuming that ½ "of concrete will need to be added to the proposed mainline and reconstruction thicknesses of 8.25" and 9.75" to allow for future diamond grinding gives proposed thicknesses of 8.75" and 10.25". For ease, these proposed thicknesses were rounded up to 9" and 10.5" and unit costs of $45.50 and $55.00 were assumed.

Dowel bar cost = $5.00/each based on information from ACPA (American Concrete Pavement Association)

Sawing and Sealing transverse joint cost = $2.50/linear foot based on information from ACPA

9.5-inch PCCP = $48.00/$Yd^2$ *from preliminary Cost Estimate
11-inch PCCP = $65.00/$Yd^2$ *from preliminary Cost Estimate

10-inch PCCP = $55.00/$Yd^2$ *from extrapolated cost based on Cost Estimate
9-inch PCCP = $45.50/$Yd^2$ * from extrapolated cost based on Cost Estimate

Total number of transverse joints @ 15-foot long panels = (11.3 x 5,280 x 2) / 15 = 7,955.2

Total number of transverse joints @ 12-foot long panels = (11.3 x 5,280 x 2) / 12 = 9,944

Total additional linear feet = (9,944 - 7,955) x 38 feet wide = 75,582 feet

Total additional dowel bars = (9,944 – 7,955) x 33 dowel bars per joint = 65,637 bars

| 'VE PROPOSAL VE-9 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 54**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF VE PROPOSAL:**<br>**Reduce concrete thickness by using shorter panels** | **Page No.: 4 of 4** |

| Construction Item | | Current Design | | | Proposed Design | | |
|---|---|---|---|---|---|---|---|
| **Item** | **Units** | **Qty** | **Unit $** | **Total** | **Qty** | **Unit $** | **Total** |
| 412-00950 Concrete Pavement (9.5") | Yd² | 469,169 | $48.00 | $22,520,112 | | | |
| 412-00110 Concrete Pavement (11") | Yd² | 32,182 | $65.00 | $2,091,830 | | | |
| 412-00975 Concrete Pavement 10.5") | Yd² | | | | 32,182 | $55.00 | $1,770,010 |
| 412-00825 Concrete Pavement (9") | Yd² | | | | 469,169 | $45.50 | $21,347,190 |
| Dowel Bars | each | | | | 65,637 | $5 | $328,185 |
| Sawing joints | Ln Ft | | | | 75,582 | $2.50 | $188,955 |
| **Subtotal** | | | | $24,611,942 | | | $23,634,340 |
| **Mark-up** | | | | 1.30 | | | 1.30 |
| **Total** | | | | **$31,995,525** | | | **$30,724,641** |
| | | | | | | **Net Cost Avoidance** | **$1,270,883** |

## 4.5 Design Comments

The **10** Design Comments developed by the VE Team are presented in this section. They are listed in the order in which they are provided in **Table 2**. Design Comments are ideas that in the opinion of the VE Team were good ideas, but for any number of reasons were not selected for development as VE Proposals. Design Comments can be notes to CDOT, a documentation of various thoughts that came up during the course of the VE Study, a reference to possible problems, suggested items that might need further study, or questions that CDOT might want to explore.

| DESIGN COMMENT DC-1 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No. 5**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF DESIGN COMMENT:**<br>**Temporary lane closures** | **Page No.: 1 of 1** |

DC-1: Idea 5: Temporary lane closures

ORIGINAL DESIGN:
The original design will construct each of the 8 interchange ramps in place, constructing the new pavement one-half at a time while maintaining traffic on the other half of the ramp.

PROPOSED DESIGN:
The proposed design would allow the contractor to close one ramp at a time for a short duration (i.e. one week or over a long weekend to allow the contractor to construct the full width pavement). Traffic would be temporarily detoured to the existing frontage road along the south side of I-70.

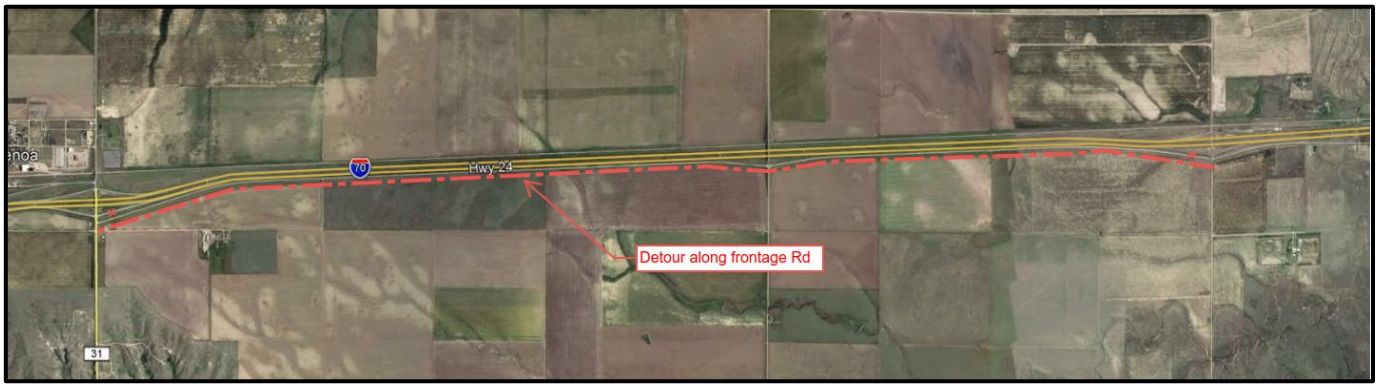
ADVANTAGES:
- Reduces construction schedule
- Improves pavement quality
- Reduces conflicts between general traffic and construction traffic
- Protects workers in construction zone

DISADVANTAGES:
- Inconvenience to the traveling public
- Potential traffic impacts to frontage road

DISCUSSION/JUSTIFICATION:
This option would allow the contractor to construct each ramp full width without the need to maintain and shift traffic. This should provide improved quality of the pavement construction, protect workers within the construction zone and reduce the potential for vehicle conflicts with construction traffic.

DISCUSSION OF RISK IMPACTS:
Potential risk of damage to existing frontage road due to increased truck traffic.

PROPOSED CHANGE SKETCH:



| DESIGN COMMENT DC-2 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 16**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF DESIGN COMMENT:**<br>**Use innovative to CDOT concrete mixtures** | **Page No.: 1 of 1** |

DC-2: Idea 16: Use innovative to CDOT concrete mixtures

ORIGINAL DESIGN:
A CDOT standard Class-P Portland Cement Concrete Pavement at both 9.5" and 11" thicknesses.

PROPOSED DESIGN:
The proposed change is to use innovative to CDOT concrete mixtures. A specific mixture is not being identified but it would be outside of CDOT standard specifications for concrete mixtures.

ADVANTAGES:
- Potential to reduce cost

DISADVANTAGES:
- Unfamiliarity to CDOT staff (designers, inspectors, etc.)
- Unfamiliarity to Contractors

DISCUSSION/JUSTIFICATION:
There are numerous different types of mixtures, some of which include newer technologies. These different types of mixtures would not meet CDOT standard specifications for mixture type but would still meet all other specifications, when applicable. When not applicable, they would meet the intent of current CDOT specifications. By using a different mixture, there is a potential to reduce the cost of concrete by potentially having a lower unit cost and/or lower quantity. Also, depending on the characteristics of the mixture, there is a potential that the concrete can be placed and cured quicker, thus compressing the schedule for this activity.

DISCUSSION OF RISK IMPACTS:
By using an innovative to CDOT concrete mixture, there is a risk of unfamiliarity to CDOT staff (designers, inspectors, etc.), as well as with contractors bidding on the project. Once a specific innovative to CDOT concrete mixture is identified, the potential cost savings might outweigh the risk of unfamiliarity. Additional special provisions would likely need to be developed.

| DESIGN COMMENT DC-3 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 20**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF DESIGN COMMENT:**<br>**Improve channelizing devices** | **Page No.: 1 of 2** |

DC-3: Idea 20: Improve channelizing devices

ORIGINAL DESIGN:
Currently the proposed design is based on CDOT standard S-630-1, Case No. 25. The traffic control plan shows “channelizing devices (fixed)”. On a similar project located on I-70 near the Genoa Project, temporary flexible delineators are being used when traffic is in a head to head configuration and it assumed that the same will be used on the Genoa Project.

PROPOSED DESIGN:
It is proposed to improve the fixed channelizing devices when traffic is in a head to head configuration. A specific type of device is not being identified, but the proposed device is assumed to be more ridged than temporary flexible delineators and/or affixed better. Additional specification for tensile strength of adhesion material is recommended.

ADVANTAGES:
- Reduces the number of devices knocked over and become a roadway hazard
- Reduces the maintenance of these devices through the work zone

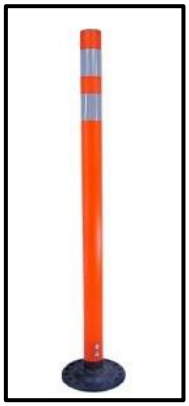
DISADVANTAGES:
- Potential cost increase
- Probable increase in roadway width when in head to head configuration
- Limits access to opposite direction of travel

DISCUSSION/JUSTIFICATION:
Based on discussions with CDOT staff and field observations of the similar, adjacent project, the flexible delineators are not staying upright as installed. It is difficult to adhere the temporary flexible delineators to the asphalt pavement with the size of base that is being used on the adjacent project. When not in place as installed, the device can become a roadway hazard and requires a maintenance crew to remove and reinstall. Given that this needs to be done near live-traffic, worker and driver safety is critical.

DISCUSSION OF RISK IMPACTS:
Using an improved channelizing device would potentially reduce the number of flexible delineators not staying upright, by either using a larger base on the flexible delineator or using a more rigid device. The issues of the delineators becoming roadway hazards and the need to maintain these devices would be reduced. More rigid devices like temporary barrier or drums will likely cost more, potentially require additional roadway width when in place and could limit access to the opposite direction of travel. The limitations on access could be an issue for emergency responders, for example.

| DESIGN COMMENT DC-3 | |
|---|---|
| **PROJECT:** 22463 I-70 Genoa Pavement Reconstruction Project | **Idea No.: 20**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF DESIGN COMMENT:**<br>**Improve channelizing devices** | **Page No.: 2 of 2** |

ORIGINAL DESIGN SKETCH:
(Assumed original channelizing device)



PROPOSED CHANGE SKETCH:
Below are examples of other devices.

| DESIGN COMMENT DC-4 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 21**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF DESIGN COMMENT:**<br>**Use portable rumble strips during construction** | **Page No.: 1 of 1** |

DC-4: Idea 21: Use portable rumble strips during construction

ORIGINAL DESIGN
This project currently has no item for portable rumble strips.

PROPOSED DESIGN:
It was suggested that the item for portable rumble strips may be added to the project to enhance the traveling public awareness of entering a work zone.

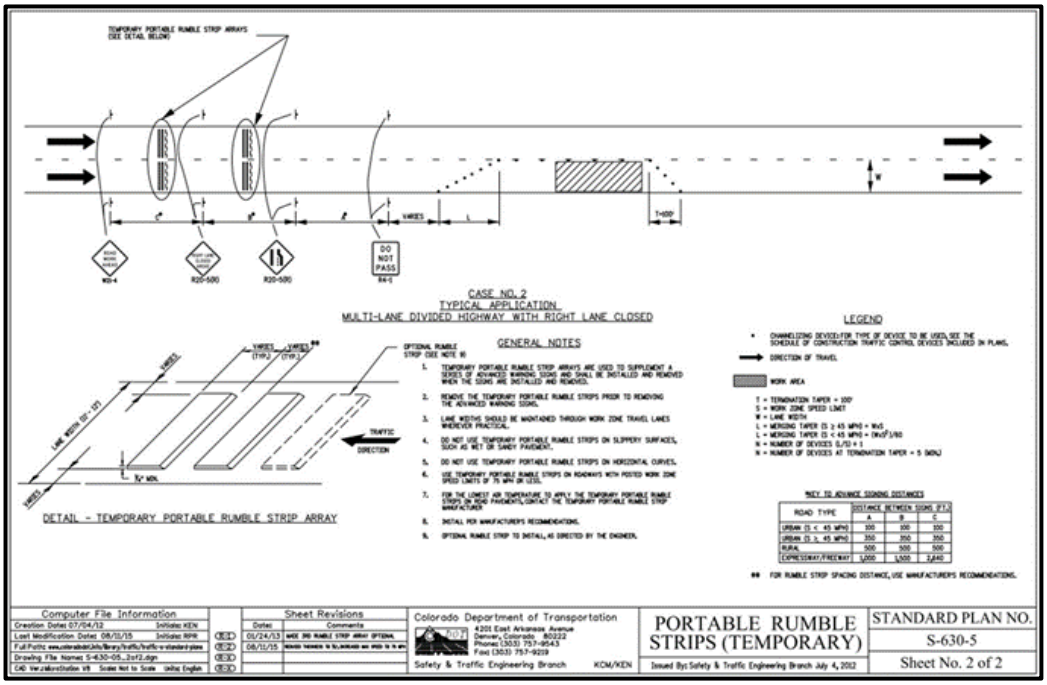
ADVANTAGES
- Alerts drivers of pattern changes

DISADVANTAGES:
- Increases cost and maintenance

DISCUSSION/JUSTIFICATION:
By adding the item Portable Rumble Strips, it may help to alert drivers of pattern changes and enhance the traveling public awareness of entering a work zone.

DISCUSSION OF RISK IMPACTS:
By adding the item Portable Rumble Strips, it may cause impacts to the traveling public if maintenance of this item needs to be addressed.

PROPOSED CHANGE SKETCH:



| DESIGN COMMENT DC-5 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 28**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF DESIGN COMMENT:**<br>**Modify density requirement for the top 6" of shoulder** | **Page No.: 1 of 1** |

DC-5: Idea 28: Modify density requirement for the top 6" of shoulder

ORIGINAL DESIGN:
The original design requires the Contractor to compact all of the installed embankment. The top six inches of embankment that is used to shoulder the new pavement also requires the seeding Contractor to rip and place their seed mixture.

PROPOSED DESIGN:
The proposed design would require the contractor to still compact all the embankment except the top six inches that receives seeding.

ADVANTAGES:
- Time and cost savings

DISADVANTAGES:
- Contractor may not place the correct amount of embankment for the top six inches

DISCUSSION/JUSTIFICATION:
The proposal eliminates the double work of compacting and then rip the compacted embankment back to its uncompacted state for the top six inches.

DISCUSSION OF RISK IMPACTS:
Small chance of Contractor not placing enough embankment to end up flush with the top of pavement.

| DESIGN COMMENT DC-6 | |
|---|---|
| **PROJECT:** 22463 I-70 Genoa Pavement Reconstruction Project | **Idea No.: 31**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF DESIGN COMMENT:**<br>**Allow a temporary on and off ramp for construction vehicles close to center of project** | **Page No.: 1 of 2** |

DC-6: Idea 31: Allow a temporary on and off ramp for construction vehicles close to center of project

ORIGINAL DESIGN:
This project currently has no phasing plans to incorporate as to where the Contractor can place their concrete plant. It is up to the Contractor to find a land owner who will lease property to the Contractor to set up their plant.

PROPOSED DESIGN:
It was suggested that if possible CDOT would allow temporary ramps to be built at county road overpasses over I-70 near the center of the project.

ADVANTAGES:
- May reduce costs and schedule
- Moves construction traffic away from travelling public
- Keeps heavy loads off of other roads

DISADVANTAGES:
- Restricts contractor plant placement

DISCUSSION/JUSTIFICATION:
This proposal would reduce construction traffic mixing in with the traveling public and would eliminate concrete haul trucks having to share on/off ramps with the traveling public at the existing on/off ramps to I-70 at Genoa and Bovina. There may be a potential for cost saving for traffic control devices, flagging and Traffic Control Management but also an increase in materials for the building and removal of the ramps. Quantifying the estimated quantities for the temporary ramp or how much savings there would be for traffic control items cannot be calculated due to unknown field conditions.

DISCUSSION OF RISK IMPACTS:
The Contractor may not be able to negotiate a reasonable price with a landowner to lease the land near this location or may get a cheaper price from other landowners in the area.

The Kyle Railroad may not be willing to let the Contractor go over their railroad or may incur costs for permits and railroads flaggers. This idea may not be feasible due to the location of railroad line being so close to the proximity of the overpass and I-70.

| DESIGN COMMENT DC-6 | |
|---|---|
| **PROJECT:** 22463 I-70 Genoa Pavement Reconstruction Project | **Idea No.: 31**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF DESIGN COMMENT:**<br>**Allow a temporary on and off ramp for construction vehicles close to center of project** | **Page No.: 2 of 2** |

PROPOSED CHANGE SKETCH:


| DESIGN COMMENT DC-7 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 42**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF DESIGN COMMENT:**<br>**Use thin white topping** | **Page No.: 1 of 1** |

DC-7: Idea 42: Use thin white topping

ORIGINAL DESIGN:
The current design is based on CDOT's Pavement Mechanistic-Empirical Design which allows the designer to analyze a PCCP overlay of 7 inches on existing asphalt.

PROPOSED DESIGN:
Use CDOT's Thin White topping spreadsheet to evaluate a potential pavement thickness below 7 inches.

ADVANTAGES:
- Reduces thickness
- Eliminates the need for dowel bars
- Reduced construction time
- Substantial cost savings
- Less impact to the public
- Profile raise maybe an advantage

DISADVANTAGES:
- Increases the number of joints
- Increases sawing and sealing of joints
- May cause a reduced service life due to the 6' by 6' panels

DISCUSSION/JUSTIFICATION:
A minimum asphalt thickness of 3 inches (after cold planning or other remedial work) is recommended. Sound evaluation of the existing pavement conditions for overlay option is recommended.

| DESIGN COMMENT DC-8 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 44**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF DESIGN COMMENT:**<br>**Reduce initial International Roughness Index (IRI) to 70 to achieve smoother pavement and reduce pavement thickness** | **Page No.: 1 of 1** |

DC-8: Idea 44: Reduce initial International Roughness Index (IRI) to 70 to achieve smoother pavement and reduce pavement thickness

ORIGINAL DESIGN:
The 2019 CDOT Pavement Mechanistic-Empirical Design (PMED) recommends the initial International Roughness Index (IRI) of 76 inches per mile for all newly constructed PCCP.

PROPOSED DESIGN:
The proposed initial IRI of 70 inches per mile is recommended as the PMED input.

ADVANTAGES:
- Reduces thickness
- Substantial cost savings
- Smoother pavement through greater IRI criteria
- More durable pavement
- Less maintenance

DISADVANTAGES:
- Potential risk to the Contractor for not achieving the targeted IRI
- May increase the amount of diamond grinding
- May cause the Contractor to reduce production
- Contractor's risk to not obtain the full quality and performance incentives
- May require the Project Engineer to revert to the original design

DISCUSSION/JUSTIFICATION:
Since implementation of this VE idea results in pavement thickness reduction, a more stringent QA/QC plan should be in place to assure achieving the goals and objectives of the design. The Contractor should have a back-up plan presented prior to the pre-pave to revisit design criteria or method of placement in case favorable results are not achieved.

| DESIGN COMMENT DC-9 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 58**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF DESIGN COMMENT:**<br>**Use Falling Weight Deflectometer (FWD) Analysis** | **Page No.: 1 of 1** |

DC-9: Idea 58: Use Falling Weight Deflectometer (FWD) Analysis

ORIGINAL DESIGN:
The design was based on thickness data from cores and subgrade samples obtained at an interval of about 2,000 feet in each direction.

PROPOSED DESIGN:
Use the Falling Weight Deflectometer (FWD) data at an interval of about 500 feet in each direction.

ADVANTAGES:
- May reduce thickness
- Evaluates the condition of the existing roadway at a greater interval
- Can determine the in-situ strength of the asphalt and subgrade material

DISADVANTAGES:
- May increase the time to design the project
- May require the design team to take additional cores to validate the data
- FWD data may have high standard error of the estimated strength

DISCUSSION/JUSTIFICATION:
A sound evaluation of the existing pavement condition at a higher frequency is recommended due to the various levels of distress noted in the original core samples. FWD data can be used to determine the overlay thickness.

| DESIGN COMMENT DC-10 | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 59**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF DESIGN COMMENT:**<br>**Undertake Ground Penetrating Radar (GPR) analysis** | **Page No.: 1 of 1** |

DC-10: Idea 59: Undertake Ground Penetrating Radar (GPR) analysis

ORIGINAL DESIGN:
The design was based on thickness data from cores and subgrade samples obtained at an interval of about 2,000 feet in each direction.

PROPOSED DESIGN:
Use the Ground Penetrating Radar (GPR) in each wheel path in each direction.

ADVANTAGES:
- May reduce thickness
- Continuously evaluates the condition of the existing roadway and subgrade
- Data can be obtained at highway speeds

DISADVANTAGES:
- May increase the time to design the project
- May require the design team to take additional cores to validate the data
- Ground penetrating radar needs a highly skilled technician to interpret the data

DISCUSSION/JUSTIFICATION:
A sound evaluation of the existing pavement condition at a higher frequency is recommended due to the various levels of distress noted in the original core samples. GPR data can be used to determine the condition of the existing asphalt and if water is present near the surface.

## 4.6 Dropped During Development

The following 3 VE Proposals were dropped during the Development Phase due to the reasons indicated.

| DROPPED DURING DEVELOPMENT | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 2**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF IDEA:**<br>**Use asphalt instead of concrete** | **Page No.: 1 of 1** |

ORIGINAL DESIGN:
The current Life Cycle Cost Analysis (LCCA) compared 9.5 inches of Class-P PCCP and 1 inch of milling to 2 inches of SMA with 9 inches of HMA over full-depth reclamation.

PROPOSED DESIGN:
Based on Chapter 13 of CDOT's 2020 Pavement Design Manual, the VE Team re-evaluated the LCCA.

ADVANTAGES:
- Reduces the comments from the Asphalt Pavement Association and the local chapter of the American Concrete Pavement Association
- Potential to advertise the project on time
- Improves the accuracy of the LCCA
- May reduce initial cost
- May allow for construction under traffic

DISADVANTAGES:
- May require the project to be re-designed
- Potential to delay the advertisement of the project
- Higher future maintenance cost

DISCUSSION/JUSTIFICATION:
The LCCA should follow the CDOT approved guidelines shown in the current version of CDOT's Pavement Design Manual.

DISCUSSION OF RISK IMPACTS:
It would require time to re-run the LCCA. It may delay the project in order to get comments from industry representatives.

| | |
|---|---|
| Base Case LCCA | Most cost-effective alternative shown was PCCP by 22.4% |
| Proposed LCCA | Most cost-effective alternative determined was PCCP by 24.3% |

ASSUMPTIONS AND CALCULATIONS:
The LCCA will use the preliminary cost estimate developed for this project.

Using Idea 3, the LCCA indicated that the 8.5-inch PCCP alternative was more cost-effective by 18.8 percent as compared to the 4 inches of grading S (100) 76-28 HMA with 4 inches of grading S (100) 64-22 HMA over 6 inches of cold in-place recycling.

| DROPPED DURING DEVELOPMENT | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No. 29**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF IDEA:**<br>**Offset the permanent ramp alignments** | **Page No.: 1 of 4** |

ORIGINAL DESIGN:
Proposed ramps at the Genoa and Bovina interchanges are currently planned to be reconstructed in their present location (i.e. no changes in alignment or profile). Proposed pavement structure will be 9" of PCCP over 6" of ABC. In order to construct the ramps, it will be necessary to either close the ramps temporarily and detour traffic, or to construct the ramps one half at a time. The ramps are used by both general traffic and construction traffic during construction which introduces the potential for accidents and conflicts.

PROPOSED DESIGN:
The proposed idea is to construct a new ramp parallel to, and alongside the existing ramp (see construction phasing sketches). Traffic would utilize the existing ramp while the new ramp is constructed. Once the new ramp is constructed, traffic would be shifted to the new ramp and the existing ramp could be utilized for construction traffic only. At the completion of construction, the existing ramps would be taken out of service and obliterated.

ADVANTAGES:
- Ramps would remain open continuously during construction
- Simplifies the construction phasing of the ramps
- Reduces the potential for conflicts between general traffic and construction traffic

DISADVANTAGES:
- Potential ROW impacts – although it appears that all of the ramps could be reconstructed without ROW impacts
- Increased project cost

DISCUSSION/JUSTIFICATION:
This idea would simplify the phasing of the interchange ramps, would allow construction traffic to fully utilize the existing ramps, and would reduce the potential for general traffic – construction traffic conflicts. This idea could be implemented on a ramp-by-ramp basis depending upon a number of factors including existing ramp traffic volumes. It could be implemented on any or all of the 8 interchange ramps.

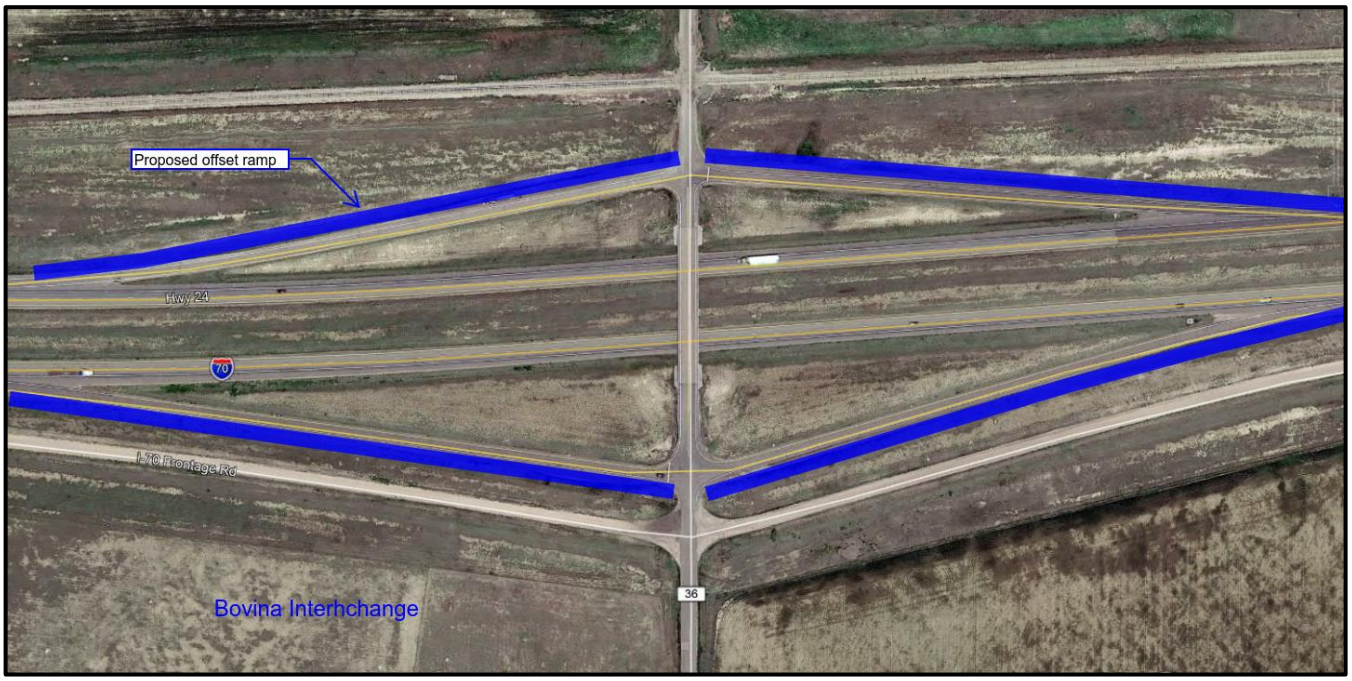
DISCUSSION OF RISK IMPACTS:
Do not anticipate any added risks related to this idea. Possibly a reduction in risk related to separation of general traffic and construction traffic.

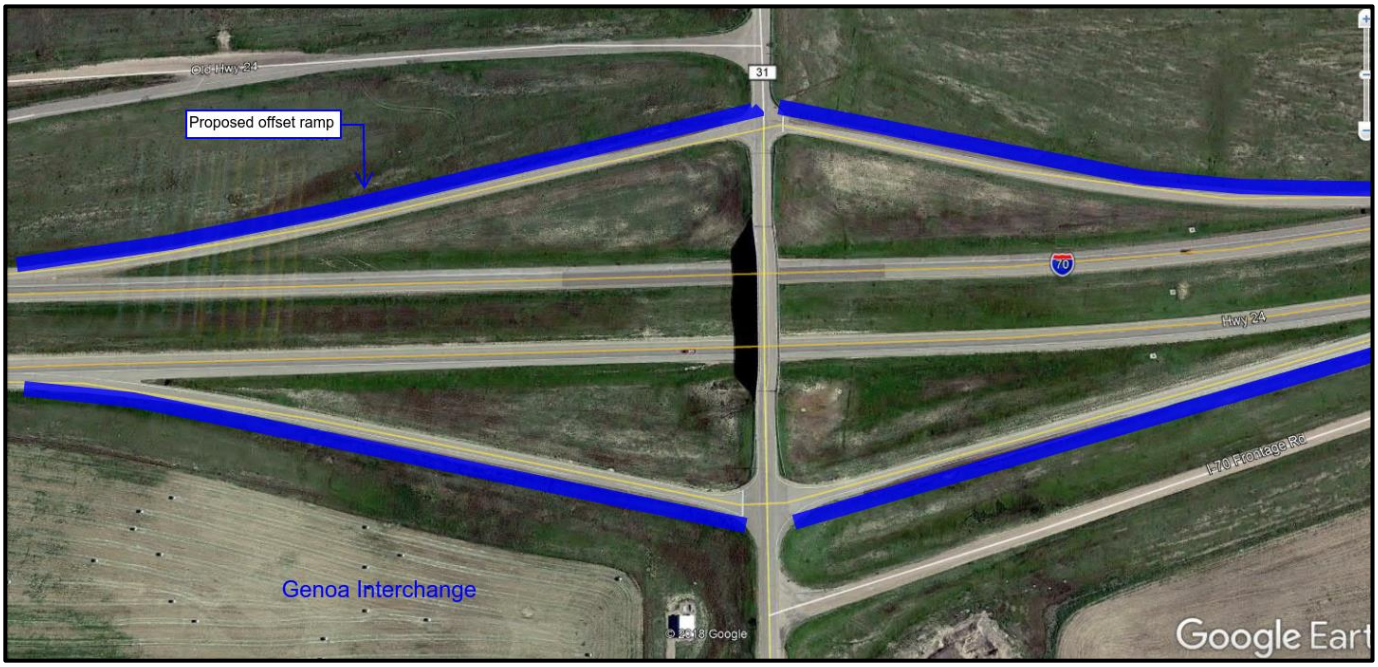
| | **Construction Costs** |
|---|---|
| Base Case Design | $0 |
| Proposed Design | **$748,704** per ramp |
| **Estimated Additional Cost** | **$748,704** per ramp |

This idea was dropped due to the significant additional cost per ramp.

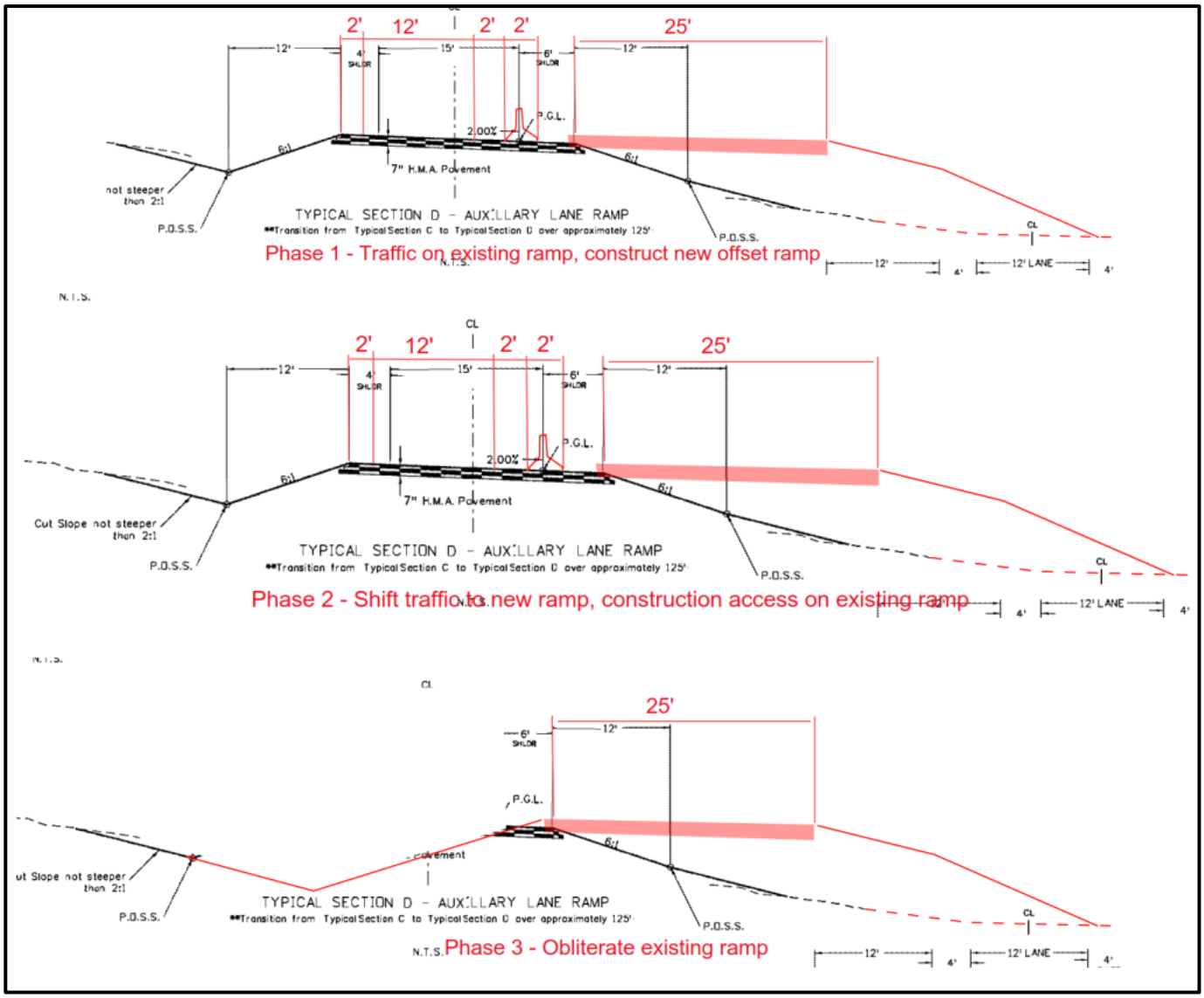
| DROPPED DURING DEVELOPMENT | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No. 29**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF IDEA:**<br>**Offset the permanent ramp alignments** | **Page No.: 2 of 4** |

PROPOSED CHANGE SKETCH:



| DROPPED DURING DEVELOPMENT | |
|---|---|
| **PROJECT:** 22463 I-70 Genoa Pavement Reconstruction Project | **Idea No. 29**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF IDEA:**<br>**Offset the permanent ramp alignments** | **Page No.: 3 of 4** |



| DROPPED DURING DEVELOPMENT | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No. 29**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF IDEA:**<br>**Offset the permanent ramp alignments** | **Page No.: 4 of 4** |

ASSUMPTIONS AND CALCULATIONS:
Unit costs are based upon 22463 I-70 Genoa FIR cost estimate and 21878 Arriba Project Bid tabs. Added a 25% contingency to cover minor items such as blading, seeding, etc. Some items including signing, striping, delineators, etc. will be the same under the base case alternative.

| Construction Item | | Current Design | | | Proposed Design | | |
|---|---|---|---|---|---|---|---|
| **Item** | **Units** | **Qty** | **Unit $** | **Total** | **Qty** | **Unit $** | **Total** |
| 202 Removal of Asphalt Mat | SY | | | $0 | 3,722 | $6.5 | $24,193 |
| 203 Embankment Material (CIP) | CY | | | $0 | 9,727 | $20 | $194,540 |
| 304 ABC Cl. 6 | CY | | | $0 | 620 | $55.65 | $34,503 |
| 410 Concrete Pavement (9 Inch) | SY | | | $0 | 3,722 | $45 | $167,490 |
| 630 Concrete Barrier (Temp) | LF | | | $0 | 1,340 | $30 | $40,200 |
| Add 25% for contingencies | | | | $0 | | | $115,000 |
| **Subtotal** | | | | $0 | | | $575,926 |
| **Mark-up** | 30% | | | $0 | | | 1.30 |
| **Total** | | | | **$0** | | | **$748,704** |
| | | | | | | **Net Cost Increase** | **$748,704** |

| DROPPED DURING DEVELOPMENT | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 35**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF IDEA:**<br>**Use precast concrete panels for mainline at ramps** | **Page No.: 1 of 4** |

ORIGINAL DESIGN:
The current design shows Class-P PCCP being installed, per specifications, with a paving machine by traditional means and methods.

PROPOSED DESIGN:
The proposed design is to use precast concrete panels for ramp tie-ins instead of traditional wet concrete paving methods. Panels could be constructed on-site, then hauled and craned into place.

ADVANTAGES:
- Less impact to the traveling public
- Potential to reduce schedule

DISADVANTAGES:
- Increase cost
- Additional labor may be needed
- Potential short impact to the traveling public

DISCUSSION/JUSTIFICATION:
The baseline concept shows Class-P PCCP being installed, per specifications, with a paving machine by traditional means and methods. Temperature and cure time requirements, amongst others, limit when the concrete can be placed and when traffic can be placed upon it. Using precast panels would reduce the impacts these two requirements have on paving. The current design is to use traditional paving means and methods up to a joint line, allow a gap in the paving for live traffic entering or exiting the highway, and then continue paving. This methodology requires a second paving pass to fill the ramp tie-in gaps. Precast concrete panels can be installed in these gaps and driven upon quicker than by traditional means and methods. Using these panels will lessen the impact on traveling public by having the ramp gore points at the same locations throughout the construction phase. This idea assumes traffic is in a head to head configuration, per the current plan set. It may lessen the impacts to the traveling public even more with an alternate phasing concept, which is an option to the Contractor. It also has the potential to reduce schedule by eliminating the second pass to fill these gaps.

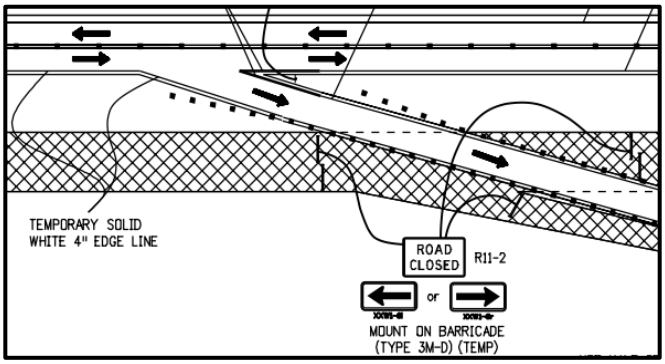
DISCUSSION OF RISK IMPACTS
Generally, using the proposed design would allow for sections of the roadway to be reopened quicker. Using the proposed design would eliminate/lessen the need for multiple gore points at on and off ramps, and the work required to construct them. There is a potential for increased costs by using the panels, but the cost could be recouped by eliminating a second paving pass. The panels may also require additional labor both in constructing and installing. Depending on the location where the panels are being used, there is the potential to need a full roadway closure, which would require a detour for a portion of the traveling public.

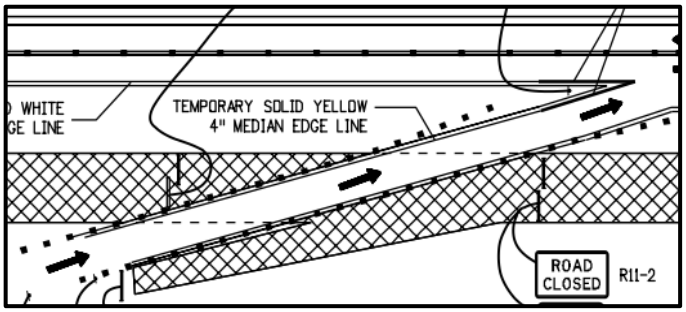
This idea was dropped due to the significant additional cost.

| DROPPED DURING DEVELOPMENT | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 35**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF IDEA:**<br>**Use precast concrete panels for mainline at ramps** | **Page No.: 2 of 4** |

| | Construction Costs |
|---|---|
| Base Case Design | $992,199 |
| Proposed Design | $7.44M |
| **Estimated Additional Costs** | **$6.48M** |

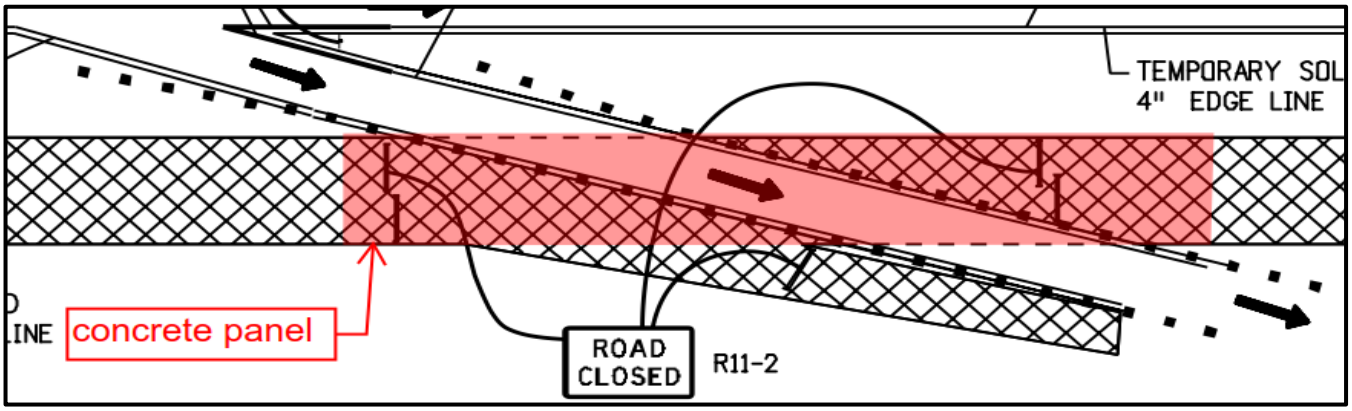
ORIGINAL DESIGN SKETCH:

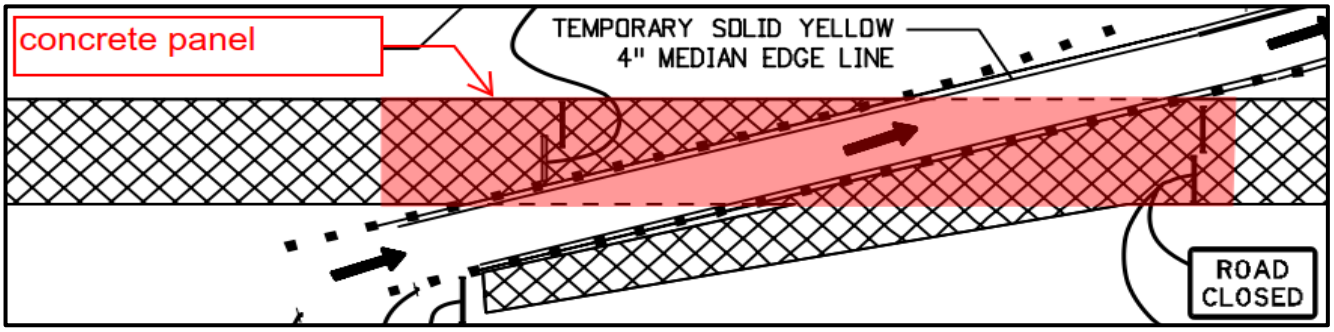



| DROPPED DURING DEVELOPMENT | |
|---|---|
| **PROJECT:** 22463 I-70 Genoa Pavement Reconstruction Project | **Idea No.: 35**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF IDEA:**<br>**Use precast concrete panels for mainline at ramps** | **Page No.: 3 of 4** |

PROPOSED CHANGE SKETCH:




| DROPPED DURING DEVELOPMENT | |
|---|---|
| **PROJECT: 22463 I-70 Genoa Pavement Reconstruction Project** | **Idea No.: 35**<br>**Date: July 11th, 2019** |
| **DESCRIPTION OF IDEA:**<br>**Use precast concrete panels for mainline at ramps** | **Page No.: 4 of 4** |

ASSUMPTIONS AND CALCULATIONS:

It is assumed that 1 ramp crossover location will be needed per ramp, as opposed to 2, as currently designed. It is assumed this single crossover location can be used for both ramps at the same milepost (1 on and 1 off). Therefore, there are 4 crossover locations. One ramp crossover area is estimated to be approximately 1,033 SY, for a total of 4,133 SY.

The gap section of pavement near one ramp gore was estimated to be approximately 704 SY and was applied to all 8 ramps, for a total of 5,632 SY.

The latest CDOT cost data for Concrete Pavement Panel (SF) in a large quantity is from 2003. A conversion to 2018 dollars was estimated based on CDOT's Construction Cost Index.

Items are based on Typical Section E as shown in current plan set.

| Construction Item | | Current Design | | | Proposed Design | | |
|---|---|---|---|---|---|---|---|
| **Item** | **Units** | **No. of Units** | **Cost / Unit** | **Total** | **No. of Units** | **Cost / Unit** | **Total** |
| 621-00450 Detour Pavement | SY | 4,133 | $55.00 | $227,315 | | | |
| 412-00950 Concrete Pavement (9.5") | SY | | | | | | |
| 412-04000 Concrete Pavement Panel (Precast) | SF | | | | 152K | $37.66 | $5.72M |
| **Subtotal** | | | | $763,230 | | | $5.72M |
| **Mark-Up** | 30% | | | $228,969 | | | $1.72M |
| **Total** | | | | $992,199 | | | $7.44M |
| | | | | | | **Net Cost Increase** | **$6.48M** |

# 5. Value Engineering Process

## 5.1 Introduction

AECOM was retained to undertake a 4-day Value Engineering (VE) Study for the 22463 I-70 Genoa East and West Pavement Reconstruction Project. The project cost estimate is $49.3M based on the CDOT Preliminary Detail Cost Estimate.

Value Engineering is a systematic process, performed by a multi-disciplinary team to analyze the functions of a project to satisfy users' needs while improving value. The VE Team identifies critical project functions and evaluates how those functions are proposed to be met in the base case design. Alternative ways are considered to achieve the equivalent functions while increasing the value of the project. The focus of a VE Study is on increasing value rather than simply reducing costs.

The Value Engineering Study was undertaken based on the scope of work and the SAVE International Value Engineering Methodology, which includes three stages: (1) Pre-Workshop; (2) Workshop; and, (3) Post-Workshop, as outlined in the following sections. **Figure 5** illustrates the activities undertaken in each stage of the VE Job Plan.

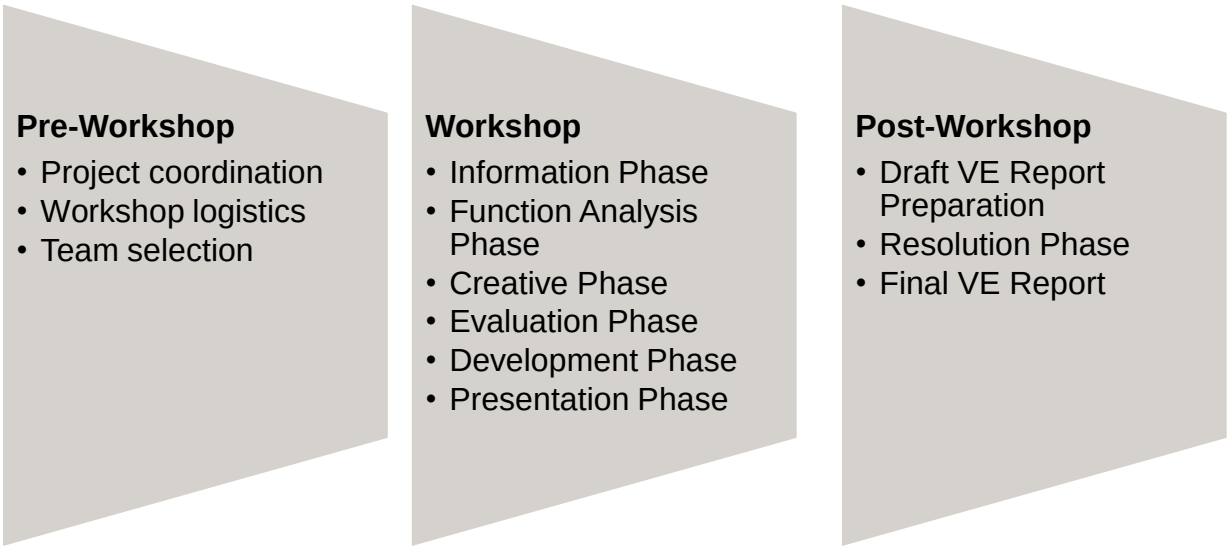



**Figure 5: VE Job Plan**

## 5.2 Pre-Workshop Activities

In the Pre-Workshop Stage, the workshop logistics were determined (i.e. location, dates, agenda); team members were identified and invited to participate in the workshop; the venue and travel arrangements were finalized; the base case information was gathered and compiled; the base

case information as well as the agenda was distributed to the team prior to the workshop; and, all required information for the completion of the workshop was gathered / completed (i.e. materials, workshop spreadsheets, etc.). The following is a list of the project documents that were provided to the VE Team for use during the workshop:

- Preliminary Detail Cost Estimate, CDOT, July 2, 2019
- FIR Meeting Summary, CDOT, Dec. 13, 2018
- Scoping Meeting Minutes, Feb. 15, 2018
- Value Engineering Notes, CDOT, July 2019
- SA#: 22463, Proj. #: NHPP 0705-086: I-70 Genoa East and West DRAFT Pavement Recommendation/Justification, CDOT, (2/1/2019)
- Special Provisions, CDOT, Dec. 13, 2018
- 60% Design Drawings, FIR, CDOT, Dec. 13, 2018

During the Pre-Workshop Stage, Pareto Cost Models were generated. Pareto's Law of Distribution states that 80% of the project costs are found in 20% of the project elements. The Pareto Cost Model is developed to:

- Organize the costs to be understood effectively
- Identify major costs elements
- Help focus the VE Team efforts on project elements with the most potential for value improvement

The Pareto Cost Models developed are included in **Appendix A.**

During the Pre-Workshop Stage, the VE Team Pavement Engineer analyzed the pavement management data for this project dating back to 1988. This information was used to understand the distresses over time and the performance of the rehabilitation historically stored on this project. This information is provided in **Appendix D**.

## 5.3 Workshop

During the workshop portion of the VE Study, the Job Plan is followed. The Job Plan is an organized approach for finding alternatives to improve value. The workshop follows an agenda which details the Job Plan and utilizes a multi-disciplinary team to arrive ultimately at the VE Team alternatives for implementation.

The Information Phase was held on July 8th, 2019, in Limon, CO. The VE Workshop was held from July 9th to July 12th, 2019 at AECOM's office in Greenwood Village, CO. The VE Results presentation was held on the morning of July 19th, 2019 at AECOM office in Greenwood Village, CO.

The Value Engineering Study was undertaken based on the scope of work and the SAVE International Value Engineering Methodology, which includes the following six (6) phases as illustrated in **Figure 6**. These six (6) key steps are described in the following subsections.


**Figure 6: Six Phase VE Job Plan**

### *5.3.1 Information Phase*

The purpose of this phase is for the VE Team to obtain a thorough understanding of the project's objectives, design, controlling decisions, issues, and constraints by reviewing the project's documents, drawings, and cost estimate. After introductions, the Value Engineering Team Leader gave a kick-off presentation. The purpose of the kick-off presentation was to provide an overview of the Value Engineering Methodology in order for all VE Team members to understand the process to be followed during the VE Workshop.

After the kick-off presentation, the design team presented the project to the VE Team. During the presentation, the goals and objectives of the VE Study were discussed and include:

- Review the 60% Design with respect to cost-effectiveness, function and the ability to meet project objectives
- To provide VE Proposals and Design Comments to increase project value through innovative ideas that improve functionality, improve schedule, improve constructability, and/or capital cost avoidance while maintaining quality and functionality

After the presentation of the base case design, the VE Team and the CDOT design team undertook a site visit. The site visit was invaluable as it provided the VE Team with further understanding of the project (**Figure 7**). During the site visit, the VE Team reviewed the Arriba Project construction site, which is a similar project to the Genoa Project.

**Figure 7: Site Visit**

### *5.3.2 Function Analysis Phase*

Function Analysis transforms the project elements into functions. A function is an expression of what something needs to do without defining how it should be done. Functions are defined in verb-noun statements to reduce the needs of the project to their most elemental level. Identifying the functions of the project provided the VE Team with an understanding of the functions required for the project. Once the functions were identified, the VE Team developed a Function Analysis System Technique (FAST) Diagram. The results of the Function Analysis Phase, as well as further information on the development of the FAST Diagram, are provided in **Appendix B**.

### *5.3.3 Creative Phase*

A VE Team's diverse background most often enhances the creative portion of the VE Workshop, and this VE Workshop was no exception. The facilitator's intent was to create an atmosphere in which team members would be willing to think creatively and "outside the box."

During the Creative Phase, the VE Team brainstormed ways to improve value in the project. A positive environment was maintained during the brainstorming session. This phase of the study was conducted as a free flow of ideas session where no idea was a bad idea and no explanations were sought or allowed. The VE Team was looking for quantity and association of ideas that would improve the value in the project. The more ideas generated, the more likely a "breakthrough" idea would be identified that would improve value.

Many of the ideas brought forth in the Creative Phase were a result of work done in the Information Phase and in the Function Analysis Phase. The resulting list of ideas was evaluated during the Evaluation Phase. A complete list of the creative ideas is provided in the Summary of Creative Ideas and Evaluation Table provided in **Appendix C**.

### *5.3.4 Evaluation Phase*

The purpose of this phase is to evaluate the ideas generated during the Creative Phase. The VE Team critically viewed each of the ideas generated during the Creative Phase of the workshop to determine whether the ideas were likely to improve the value of the project.

After the VE Team listed the advantages and disadvantages for each of the ideas, each idea was evaluated in terms of its potential impact to performance, cost, time, and risk. Once each idea was fully evaluated, it was given a total rating number based on a scale of 1 to 7.

Ideas rated 4 to 7 were developed further. The VE Team reviewed each of the ideas scoring 4 to 7 to determine which ideas could be developed as VE Proposals. The ideas where cost impacts could not be determined were developed as Design Comments. A "Carried Forward" (CF) scoring was given to VE Proposals. A "Design Comment" (DC) score was given to the ideas that the VE Team thought had potential to improve value but did not have the information or time to fully explore the idea. Only ideas that scored a "CF" or "DC" were evaluated further during the Development Phase. The results of the Evaluation Phase are provided in the Summary of Creative Ideas and Evaluation Tables provided in **Appendix C**.

### *5.3.5 Development Phase*

VE Team members were assigned the CF and DC ideas to develop into VE Proposals or Design Comments based on their areas of expertise. The developer was instructed to use the entire team as a resource in the development of the idea. VE Proposals and Design Comments were developed as far as time and resources would allow during the VE Workshop.

Each VE Proposal included a summary of the base case design, a description of the suggested change, a list of advantages and disadvantages of the VE Proposal compared to the base case design, a brief narrative comparing the base case design with the VE Proposal, and a comparison of the costs associated with the base case design relative to the proposed change. Sketches of the base case and proposed design were also provided, if applicable. Design Comments were also developed to the same level of detail as the VE Proposals, but no costs were estimated. The completed VE Proposals and Design Comments are provided in **Section 4** of this report.

### *5.3.6 Presentation Phase*

The VE Study results were presented to the CDOT staff on the morning of July 19th, 2019. In addition to the VE Team, the presentation attendees from CDOT included:

- Travis Miller, PE, Limon Resident Engineer
- Rhianna Poss, P.E., Genoa Project Manager
- Karl Larson, CEPM I, Construction and Design
- James Miller, PE, Bethune Project Manager
- Michael Hines, EPST II, Design
- Corey Stewart, PE III North Program Engineer
- Keith Sheaffer, PE III South Program Engineer
- Gary DeWitt, PE II Region 4 Materials Engineer
- Steven Heimmer, PE I

## 5.4 Post-Workshop Activities

The Post-Workshop activities for this project included:

- **Draft VE Report:** Prepare and submit the Draft VE Report, which provides a complete documentation of the VE Study
- **Resolution Phase:** CDOT reviewed and determined the disposition of all VE Proposals and Design Comments
- **Final VE Report:** Finalization of the Draft VE Report based on the comments received

# Appendix A Pareto Cost Model

## A.1 Pareto Cost Model

Pareto Cost Models are used to understand where the majority of the project resources are being allocated. Pareto's Law of Distribution states that 80% of the project costs are found in 20% of the project items. A Pareto Cost Model is developed to:

- Organize the costs in order for them to be understood effectively
- Identify where the major costs are to be found
- Help focus the Value Engineering Team efforts on project elements with the most potential for value improvement

**Table 4** and **Figure 8** provide the Pareto Cost Model for Overall Project Summary developed using the Biddable Items in the CDOT Preliminary Detail Cost Estimate provided to the VE Team. The items highlighted in yellow illustrate where 80% of the costs are in the project.

**Table 4: Pareto Cost Model Table – Overall Project Summary (Biddable)**

| Items | Cost | % of Project | Total % |
|---|---|---|---|
| Roadway | $41,162,509 | 99.0% | 99.0% |
| Structures (EB) | $169,758 | 0.4% | 99.5% |
| Structures (WB) | $147,583 | 0.4% | 99.8% |
| Construction Engineering Bid | $79,500 | 0.2% | 100.0% |
| | **$41,559,350** | **100.0%** | |

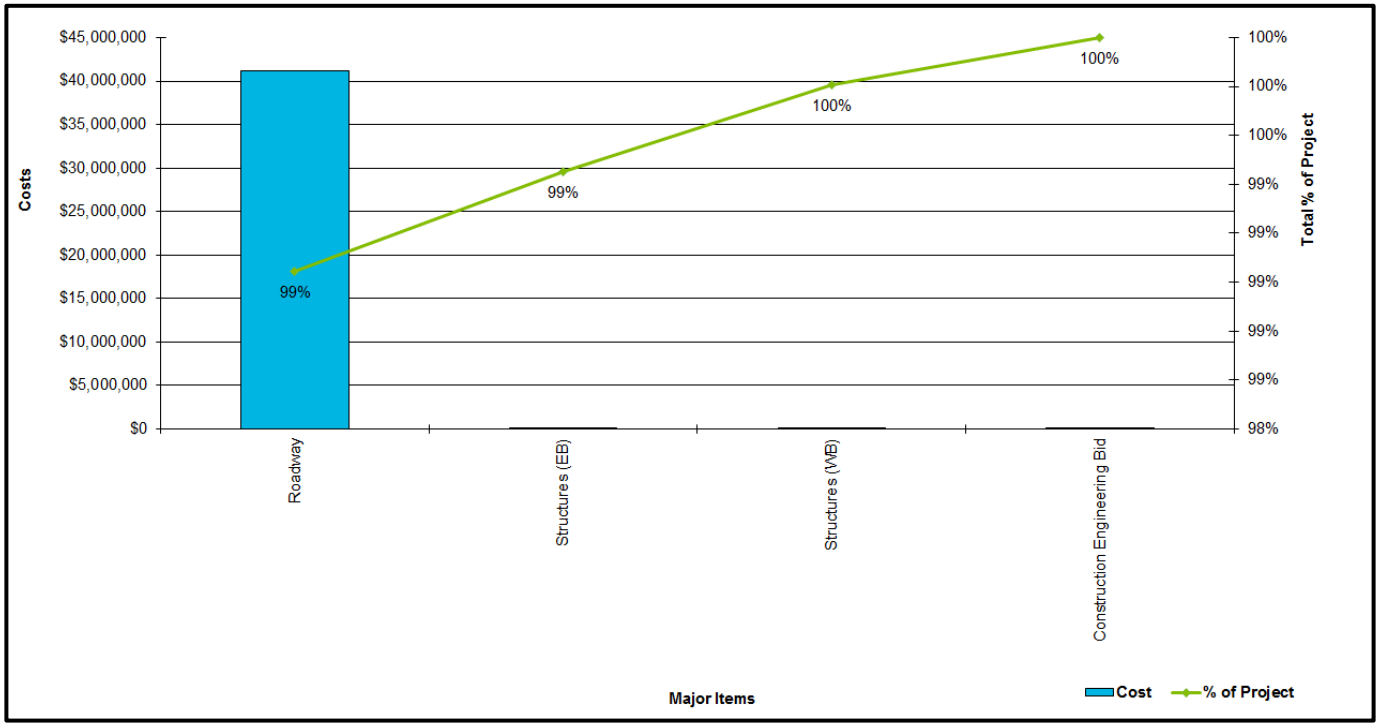



**Figure 8: Pareto Cost Model – Overall Summary (Biddable)**

**Table 5** and **Figure 9** provide the Pareto Cost Model for the Biddable Roadway Items developed using the CDOT Preliminary Detail Cost Estimate provided to the VE Team. The items highlighted in yellow illustrate where 80% of the costs are in the project for the roadway. Note: The Biddable Roadway costs do not include all forced Account (F/A) and mobilization costs, which account for $10,112,000.

**Table 5: Pareto Cost Model Table – Roadway (Biddable)**

| Items | Cost | % of Project | Total % |
|---|---|---|---|
| Concrete Pavement (9-1/2 inch) | $21,900,960 | 70.5% | 70.5% |
| Concrete Pavement (11 inch) | $2,930,265 | 9.4% | 80.0% |
| Embankment Material (Complete in place) | $1,791,820 | 5.8% | 85.7% |
| Removal of Asphalt Mat (Planing) | $1,253,378 | 4.0% | 89.8% |
| All Other Items Less than $100,000 | $813,995 | 2.6% | 92.4% |
| Detour Pavement | $586,410 | 1.9% | 94.3% |
| Aggregate Base Course (Class 6) | $417,987 | 1.3% | 95.6% |
| Concrete Safety Edge | $356,223 | 1.1% | 96.8% |
| Preformed Plastic Pavement Marking (Type II) Inlaid) | $316,316 | 1.0% | 97.8% |
| Traffic Control Management | $280,575 | 0.9% | 98.7% |
| Removal of Ground Sign | $169,500 | 0.5% | 99.2% |
| Flagging | $128,000 | 0.4% | 99.7% |
| Pavement Marking Paint (High Build) (Inlaid) | $105,080 | 0.3% | 100.0% |
| | **$31,050,509** | **100.0%** | |

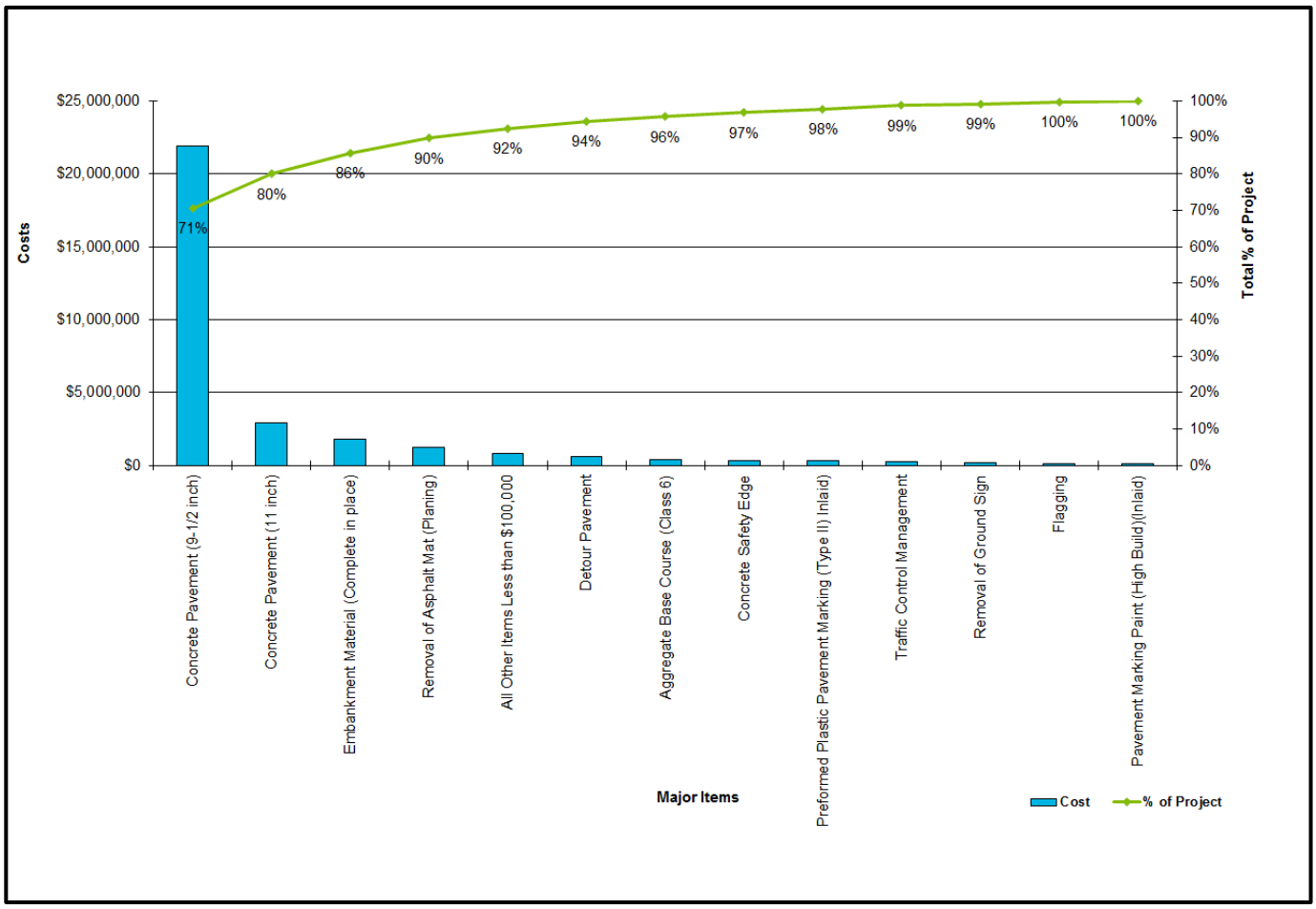



**Figure 9: Pareto Cost Model – Roadway (Biddable)**

# Appendix B Function Analysis

## B.1 Function Analysis

Function Analysis was undertaken by the VE Team to develop an understanding of the functions that the project must achieve to satisfy the owner. A function is an expression of what something needs to do without defining how it should be done. Functions are defined in active verb / measureable noun statements to reduce the needs of the project to their most elemental level. Identifying the functions of the major project elements allows alternative solutions to be generated to accomplish those functions. **Table 6** provides the functions of the project identified by the VE Team.

**Table 6: Project Functions**

| Element | Functions | Functions |
|---|---|---|
| Overall Project | Improve Safety<br>Move Vehicles Efficiently<br>Increase Rideability<br>Reduce Maintenance<br>Increase Service Life<br>Extend Structure Life<br>Maintain Vertical Clearance<br>Improve Ramp Section<br>Replace Signage<br>Maintain Traffic<br>Improve Illumination<br>Reduce Distresses | Improve Drainage<br>Improve Skid Resistance<br>Improve Cross-Slope<br>Meet Standards<br>Improve Recovery Area Improve<br>Emergency Turnarounds<br>Reduce Accidents<br>Improve Lane Delineation<br>Verify Quality<br>Stabilize Existing Subbase |

## B.2 Function Analysis System Technique (FAST) Diagram

The Function Analysis System Technique (FAST) Diagram shown in **Figure 10** graphically illustrates the functions in logical order. A function diagram organizes the identified functions into the "How-Why" logic model. Proper arrangement and relationship of the functions in the function diagram can be confirmed with the How-Why logic test as follows:

- Ask the question of any function, "**How** do I verb-noun?" The answer should be the function to the immediate **right**.
- Ask the question "**Why** do I verb-noun?" The answer should be the function to the immediate **left** (i.e., "so that I can verb-noun?").
- A function that does not pass the How-Why test is either described improperly or is in the wrong place. The answer must make sense.

The farther you proceed from left to right in the diagram, the more precise you become. Conversely, the farther you proceed from right to left, the more general you become. It is important to understand that the position of functions in a functional diagram in no way represents the chronological order of events. The intent of the FAST Diagram is to help the VE Team consider the logic of how and why something is done, as well as the importance and relevance of each function.

Some of the functions listed in **Table 6** may not be included in the FAST Diagram because they were not considered critical functions when the diagram was created. In addition, some of the critical functions in the FAST Diagram are not listed above because they were not identified until the diagram was created.

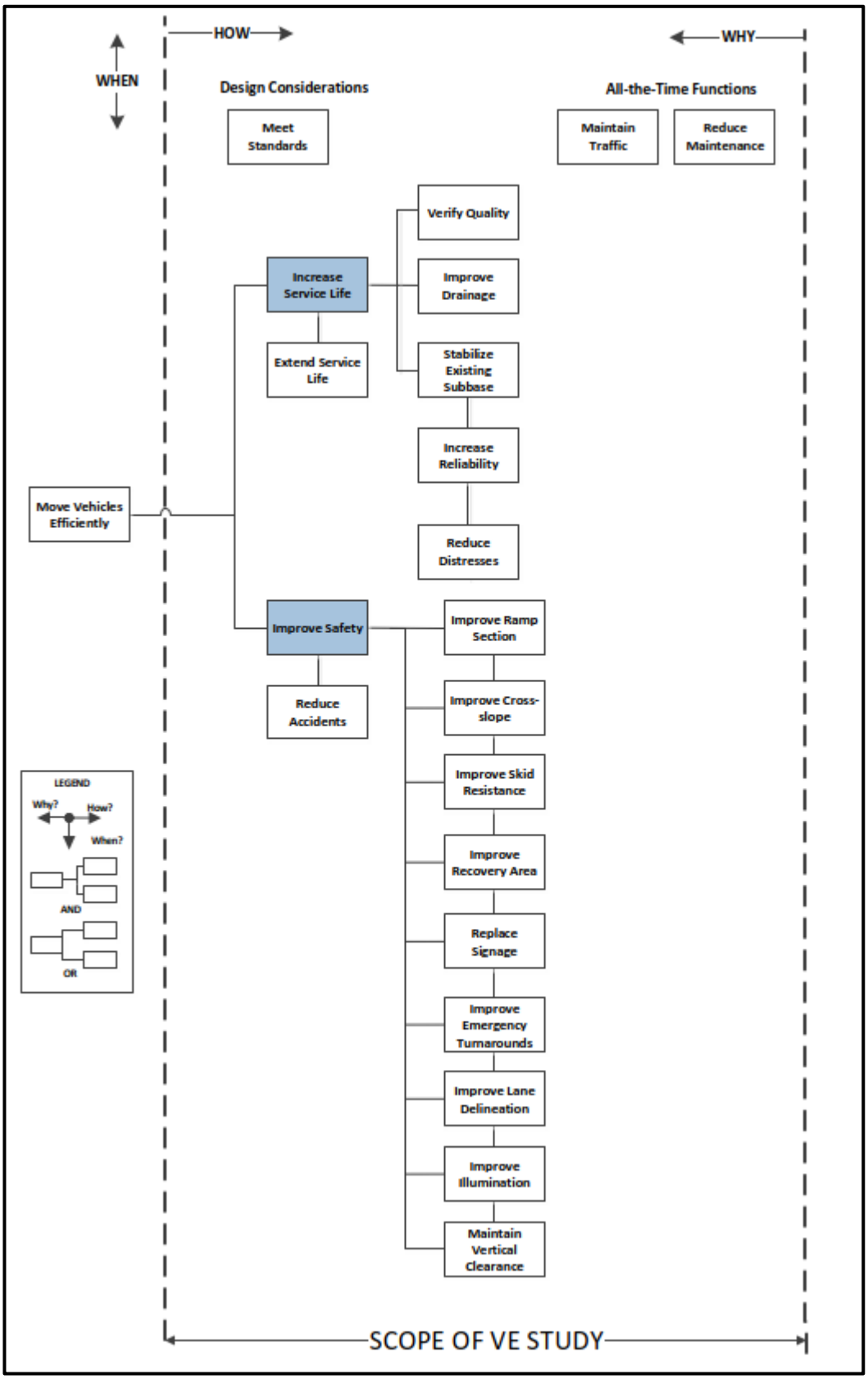



**Figure 10: FAST Diagram**

# Appendix C Creative Phase and Evaluation Table

## C.1 Creative Phase and Evaluation Table

During the Creative Phase of the VE Study, the VE Team was encouraged to offer any and all ideas, including “wild ideas” or “out of the box” ideas, to perform the intended functions of the project. A positive environment for brainstorming was maintained at all times, reserving all judgment of the ideas until the Evaluation Phase so that all VE Team members would be comfortable offering thoughts and ideas. The VE Team was looking for quantity and association of ideas. The more ideas generated, the more likely a “breakthrough” idea would be identified with significant value implications.

During the Evaluation Phase, the VE Team critically viewed each of the ideas generated during the Creative Phase of the workshop to determine whether the ideas were likely to improve the value of the project. After the VE Team listed the advantages and disadvantages for each of the ideas, each idea was evaluated in terms of its potential impact to performance, cost, time, and risk. Once each idea was fully evaluated, it was given a total rating number. This is based on a scale of 1 to 7, as indicated by the following rating index:

| | |
|---|---|
| 7 = Major Value Improvement | These ratings represent the subjective opinion of the VE Team regarding the potential benefits of the concepts in order to prioritize them for development. |
| 6 = Moderate Value Improvement | |
| 5 = Minor Value Improvement | |
| 4 = Possible Value Improvement | |
| 3 = Minor Value Degradation | Concept results in a minor cost or performance improvement at the expense of the other. |
| 2 = Moderate Value Degradation | Concept reduces cost but creates an unacceptable degradation to performance. |
| 1 = Major Value Degradation | Concept is not technically feasible or does not meet project need and purpose. |

Ideas rated 4 to 7 were developed further. The VE Team reviewed each of the ideas scoring 4 to 7 to determine which ideas could be developed as VE Proposals. The ideas where cost impacts could not be determined were developed as Design Comments. **Table 7** provides the results of the Creative Phase and Evaluation Phase. Ideas scoring 4 to 7 which were developed as VE Proposals are indicated as “Carried Forward (CF)”. Design Comments are indicated as “DC”. The following legend was used by the VE Team to determine which ideas to develop as VE Proposals and Design Comments generated during the Creative Phase:

- CF: Carried Forward = Idea to be developed into a VE Proposal
- DC: Design Comment = Idea to be developed into a Design Comment
- NCF: Not Carried Forward = Idea rejected by the VE Team
- W: With = Idea is being developed with another idea
- DDD: Dropped During Development = Idea was determined to not be feasible
- ABD: Already Being Done = Idea is already being done in the base case design
- CM&M: Construction Means and Methods = Idea is a good idea, but it is Construction Means and Method that is to be determined by the contractor

## Table 7: Creative Ideas and Evaluation Table

| Idea No. | Description | Advantages | Disadvantages | Evaluation Ranking | VE Team Action |
|---|---|---|---|---|---|
| 1 | Accelerate schedule | Potential to reduce cost; Less inconvenience to the travelling public | Potential to increase costs | 4 | CF |
| 2 | Use asphalt instead of concrete | Potential reduction in initial costs; Allows construction under traffic; Smoother than concrete | Higher maintenance costs; Potential reduction in service life | 4 | DDD |
| 3 | Re-evaluate the concrete design | Reduces costs; Reduces schedule; Reduces gain in elevation | Potential to reduce service life; Redesign required | 6 | CF |
| 4 | Optimize milling | Reduces schedule; May not impact destabilized HMA | Thicker concrete; Meeting cross-slope | 4 | CF |
| 5 | Temporary ramp closures | Reduces schedule; Improves quality | Inconvenience to the travelling public | 4 | DC |
| 6 | Use glass grid for asphalt | Eliminates milling; Eliminates any pre-overlay work; Reduces schedule | Increases initial costs; Does not improve drainage | 4 | with Idea 2 |
| 7 | Full depth reclamation | Stabilizes the subgrade; Reusing materials | Increases costs; Increases schedule; Potential to expose subgrade | 4 | with Idea 2 |
| 8 | Cold in place recycling | Stabilizes the subgrade; Reusing materials; Does not impact subgrade | Potential to increase costs and schedules | 4 | with Idea 2 |
| 9 | Use different typical eastbound and westbound pavement sections | Reduces costs; Potential to reduce schedule | None identified | 3 | NCF |
| 10 | Variable typical cross section (i.e. driving, passing and shoulders are different) | Potential to reduce costs | Possible problems with cracking; Potentially harder to construct; Potential quality issues | 3 | NCF |
| 11 | Use less dowel bars | Reduces costs | Will not meet current standards | 3 | NCF |
| 12 | Use widened lanes | Reduces thickness; Reduces costs; Reduces distresses at the sawcut | The travelling public uses it as a lane guide; Increases dowels | 6 | CF |

| Idea No. | Description | Advantages | Disadvantages | Evaluation Ranking | VE Team Action |
|---|---|---|---|---|---|
| 13 | Minimal vertical clearances at the bridges | Reduces costs; Reduces construction time; Avoids unstable subbase | May not have room for future overlays | 4 | CF |
| 14 | Use moveable temporary crossovers | Ability to reuse materials | Unproven methodology | 3 | NCF |
| 15 | Leave temporary crossovers in place | Used to move traffic to other side of the road in case of an incident; Eliminates cost of demo | Travelling public using it to make a U-Turn; Permanent drainage required | 3 | NCF |
| 16 | Use innovative to CDOT concrete mixtures | Potential to reduce costs | Unknown to CDOT and potentially unknown to contractors | 4 | DC |
| 17 | Use higher strength concrete | Reduces thickness; Reduces schedule | Potential to increase costs | 4 | CF |
| 18 | Eliminate R value for the shoulders outside roadway prism | Reduces costs; Potential to reduce schedule | High variability in material | 6 | ABD |
| 19 | Half width typical paving for each direction | Removes head to head traffic during construction | Mix of drivers and construction personnel; Increases costs; Increases schedule; Harder to construct; Construction joint in the middle of the road | 3 | NCF |
| 20 | Improve channelizing devices | Reduces number of devices knocked over: Reduces maintenance | Increases cost; Additional width may be required | 4 | DC |
| 21 | Use portable rumble strips during construction | Alerts drivers of pattern changes | Increases cost and maintenance | 4 | DC |
| 22 | Use movable channelizing barrier | Reduces potential for head on head collisions | Increases costs; Increases width requirements; Increases costs and schedule | 3 | NCF |
| 23 | Use millings generated on project for subbase material | Reduces costs; Reduces schedule | Potential to trap water | 5 | CF |

| Idea No. | Description | Advantages | Disadvantages | Evaluation Ranking | VE Team Action |
|---|---|---|---|---|---|
| 24 | Use asphalt instead of concrete on the ramps | Reduces schedule and closure time of ramps | Increases costs; Reduces quality; Potential to increase maintenance | 4 | with Idea 2 |
| 25 | Lower the grade profile to existing (i.e. saves signage, embankments, etc.) | Saves from moving signage and quantity of the embankment | Changes typical section | 3 | NCF |
| 26 | Use square yard and cubic yard to pay for concrete | Contractor is paid for all materials installed in the project; Allows for contractor innovation | Potential for contractor to overrun quantity costs | 3 | NCF |
| 27 | Modify mix design for seeding | Reduces costs | Potential to reduce pollination | 2 | NCF |
| 28 | Modify density requirements for top 6" of shoulders | Easier to seed; Reduces schedule; Reduces costs | Possible settlement issues | 5 | DC |
| 29 | Offset the permanent ramp alignments | Ramps would remain open during construction; Reduces phasing | Potential right-of-way impacts; Increases costs | 5 | DDD |
| 30 | Use Frontage Roads for temporary on and off ramps | Could close a ramp during construction | Inconvenience to the travelling public; Only works on half of the Interstate | 2 | NCF |
| 31 | Allow a temporary on and off ramp for construction vehicles close to center of project | Reduces costs and schedule; Moves construction traffic away from travelling public; Keeps heavy trucks off of other roads | Restricts contractor plant placement | 4 | DC |
| 32 | Allow concrete conveyor bridge for construction | Do not have to move the plant; Reduces distresses on other roads | Potentially reduces quality of concrete; Potential visual distraction | 4 | CM&M |
| 33 | Allow for a longer construction season (i.e. allow construction to start sooner and end later) | | | | ABD |
| 34 | Use incentive / disincentive for early completion with variances allowed on hours and days of operation | Reduces schedule; Reduces impacts to travelling public | Potential to increase costs; Additional CDOT staff required; Not common in this area; Potential for increase in claims | 3 | NCF |

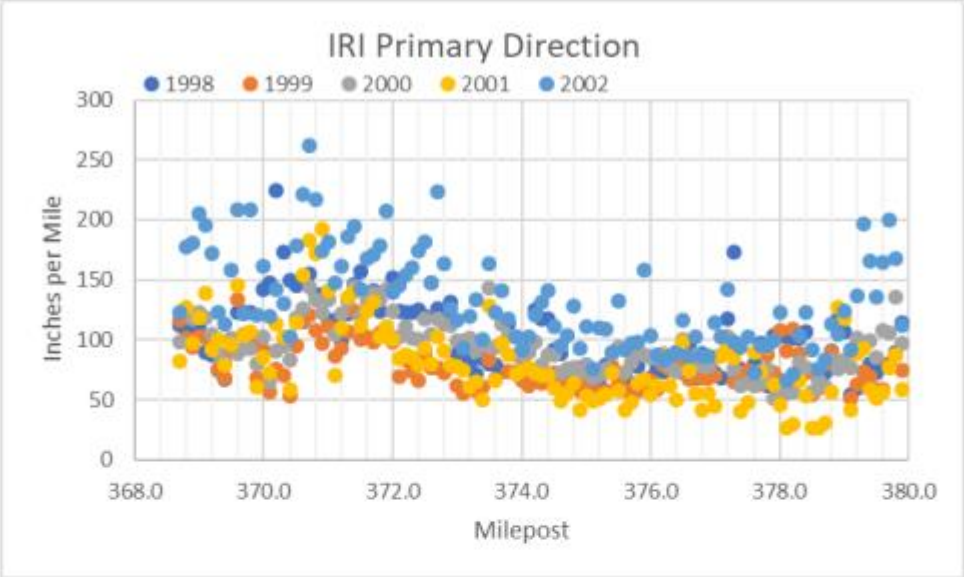
| Idea No. | Description | Advantages | Disadvantages | Evaluation Ranking | VE Team Action |
|---|---|---|---|---|---|
| 35 | Use precast concrete panels for mainline at ramps | Less impact to the travelling public; Reduces schedule | Increases costs | 5 | DDD |
| 36 | Use other materials for bridge rehab | Reduces costs; Reduces schedule | Potential to reduce service life; Redesign required; Requires structural staff approval; Not on approved product list | 3 | NCF |
| 37 | Do nothing | Reduces costs | Does not address the purpose and need of the project | 1 | NCF |
| 38 | Use asphalt shoulders | Delineates between travel lanes and shoulder | Potential for drainage issues and cracking if mainline is concrete; Potential to increase schedule | 2 | NCF |
| 39 | Use roller compacted concrete for the crossovers | Reduces costs; Reduces time to construct the crossover | Quality control may be an issue | 3 | NCF |
| 40 | Issue westbound reconstruction as a separate contract if funding is limited | Makes use of available funding | Does not address the purpose and need of the project | 3 | NCF |
| 41 | Use drainage fabric layer underneath the pavement | Improves drainage; Reduces schedule; Increases service life | Increases costs; Potentially unknown to contractors; Potential to impact future rehabilitation | 3 | NCF |
| 42 | Use thin white topping | Reduces costs; Reduces schedule | Increases joints and sawing; Increases maintenance | 4 | DC |
| 43 | Use fibers in the concrete mix with bars | Reduces crack width; Increases strength; Potential to reduce maintenance; Potential to increase service life | Increases costs; Potential of reduce quality | 3 | NCF |
| 44 | Reduce initial International Roughness Index (IRI) to 70 to achieve smoother pavement and reduce pavement thickness | Reduces thickness; Reduces schedule | Potential for more diamond grinding | 4 | DC |
| 45 | Reuse unsuitable material for shouldering | Reduces costs; Reduces schedule | Time required for drying | 4 | CF |

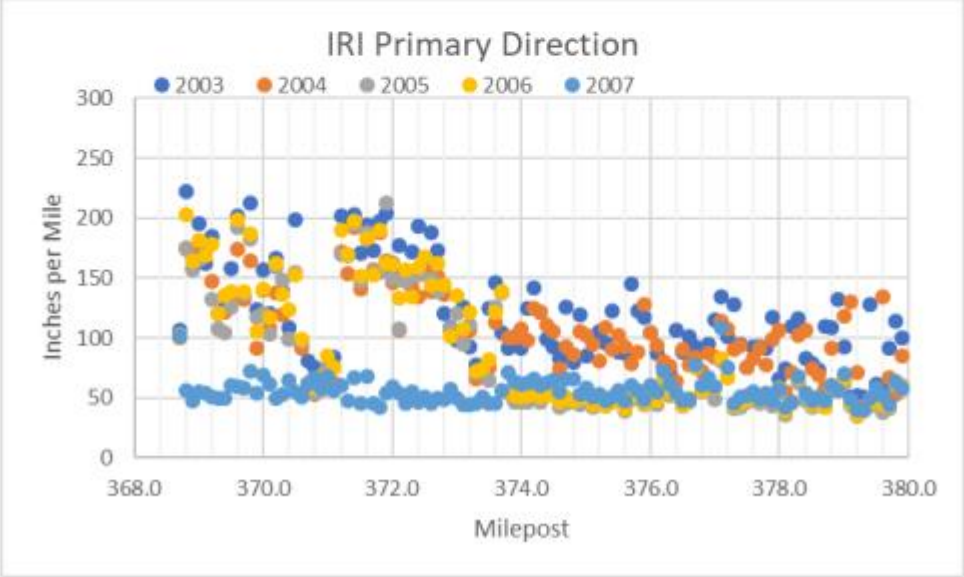
| Idea No. | Description | Advantages | Disadvantages | Evaluation Ranking | VE Team Action |
|---|---|---|---|---|---|
| 46 | Use a long-term warranty | Reduces CDOT risk; Reduces maintenance for warranty period; Improves contractor quality | Increases initial costs; Reduces maintenance costs during warranty period; Additional CDOT effort | 3 | NCF |
| 47 | Use alternative delivery methods | Allows for innovation; Potential to reduce schedule; Transfers risk to contractor | Increases costs; Harder to track; Plans are passed Design-Build | 2 | NCF |
| 48 | Allow use of crushed concrete in the mix design | | | | ABD |
| 49 | Use the millings from asphalt in concrete as an aggregate | Reuses material; Reduces costs | Potential for lower flexural strength | 3 | NCF |
| 50 | Use hot in place recycling | Eliminates need for milling | Increases costs | 2 | NCF |
| 51 | Use high performance dowel bars | Increases service life; Potential to reduce the number of bars | Increases costs | 2 | NCF |
| 52 | Use chemically stabilized base to reduce subbase (only in cut areas) | Reduces schedule; Uses existing material | Mobilize another crew; Potential to increase costs | 3 | NCF |
| 53 | Use biaxial geogrid for the cut areas | Reduces schedule; Uses existing material | Potential to increase costs | 3 | NCF |
| 54 | Reduce concrete thickness by using shorter panels | Potential to reduce thickness; Potential to reduce costs | Increases sawing and dowel bars | 4 | CF |
| 55 | Use ultra thin white topping | Reduces costs and schedule | Design not feasible | 3 | NCF |
| 56 | Use various dowel bar sizes | Potential cost savings | Confusion for the contractor; Potential for reduced quality | 2 | NCF |
| 57 | Use various thicknesses for PCCP based upon the subgrade | Reduces costs; Reduces schedule | Increases design effort; Potential for constructability issues | 3 | NCF |
| 58 | Undertake Falling Weight Deflectometer (FWD) analysis | Potential to reduce costs; Allows other design options | Potential scheduling issues | 4 | DC |
| 59 | Undertake Ground Penetrating Radar (GPR) analysis | Potential to reduce costs; Allows other design options | Potential scheduling issues | 4 | DC |

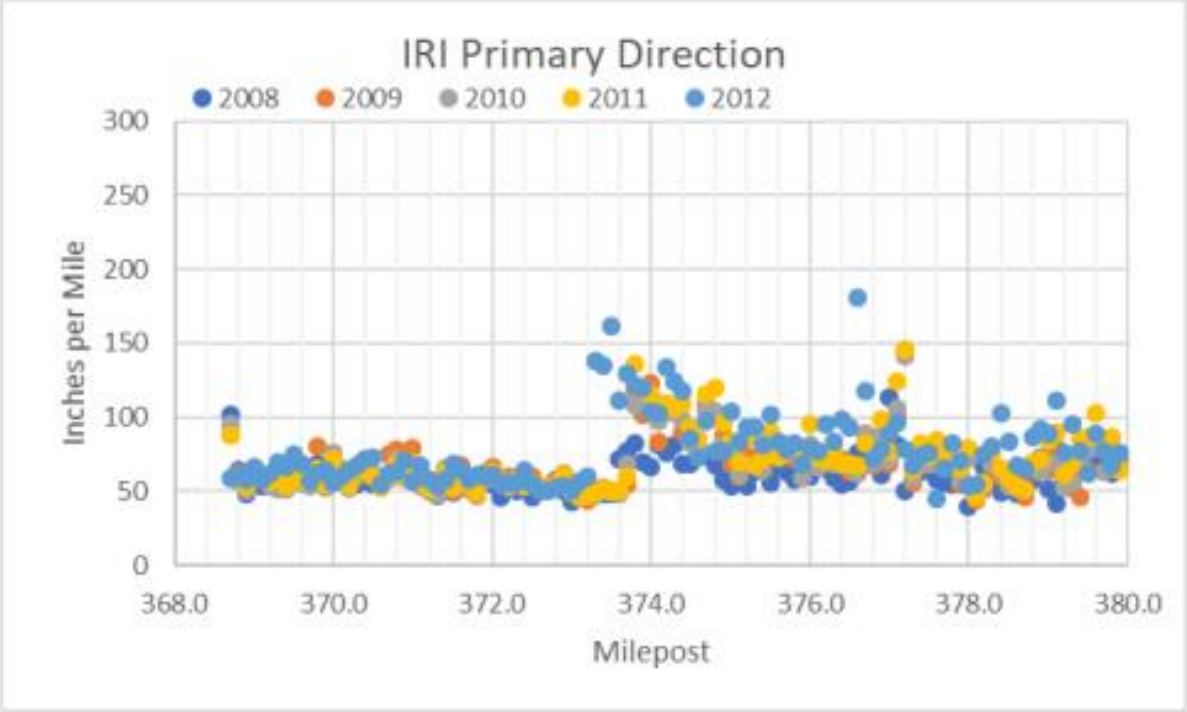
| Idea No. | Description | Advantages | Disadvantages | Evaluation Ranking | VE Team Action |
|---|---|---|---|---|---|
| 60 | Use InRoads Analysis for determining overlay vs reconstruct areas | Identifies more accurate overlay vs reconstruct and milling areas | Unknown to CDOT staff; LIDAR survey required | 3 | NCF |

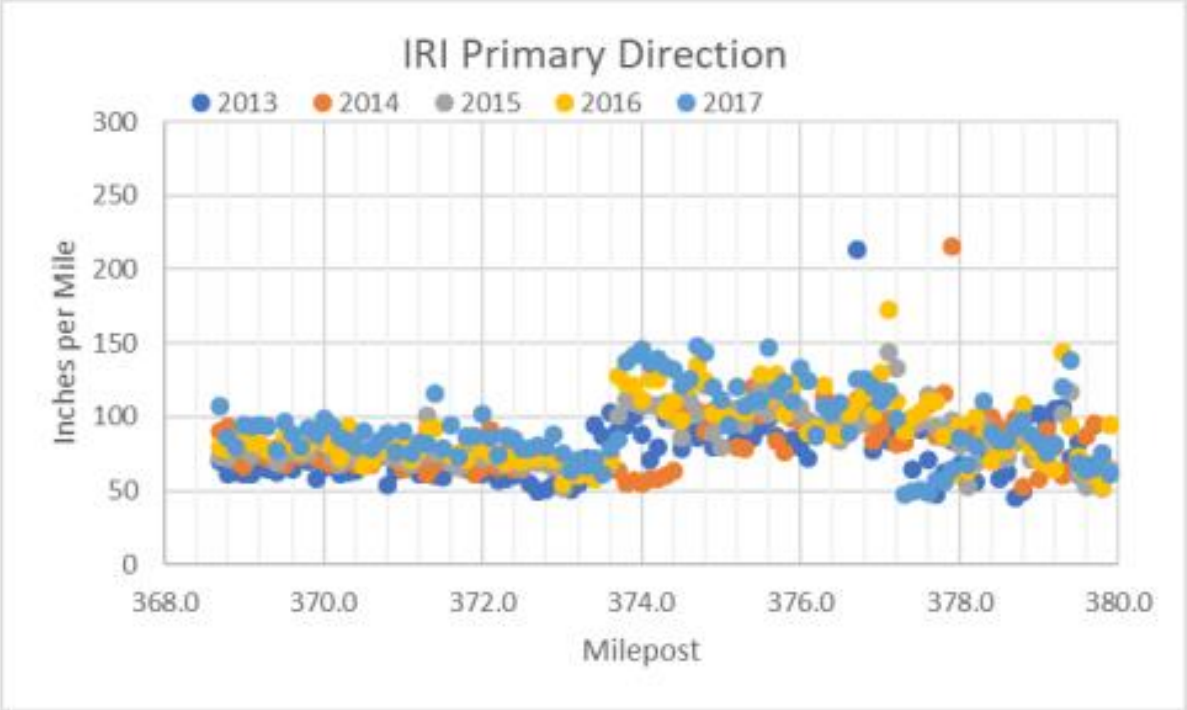
# Appendix D Pre-Workshop Pavement Analysis

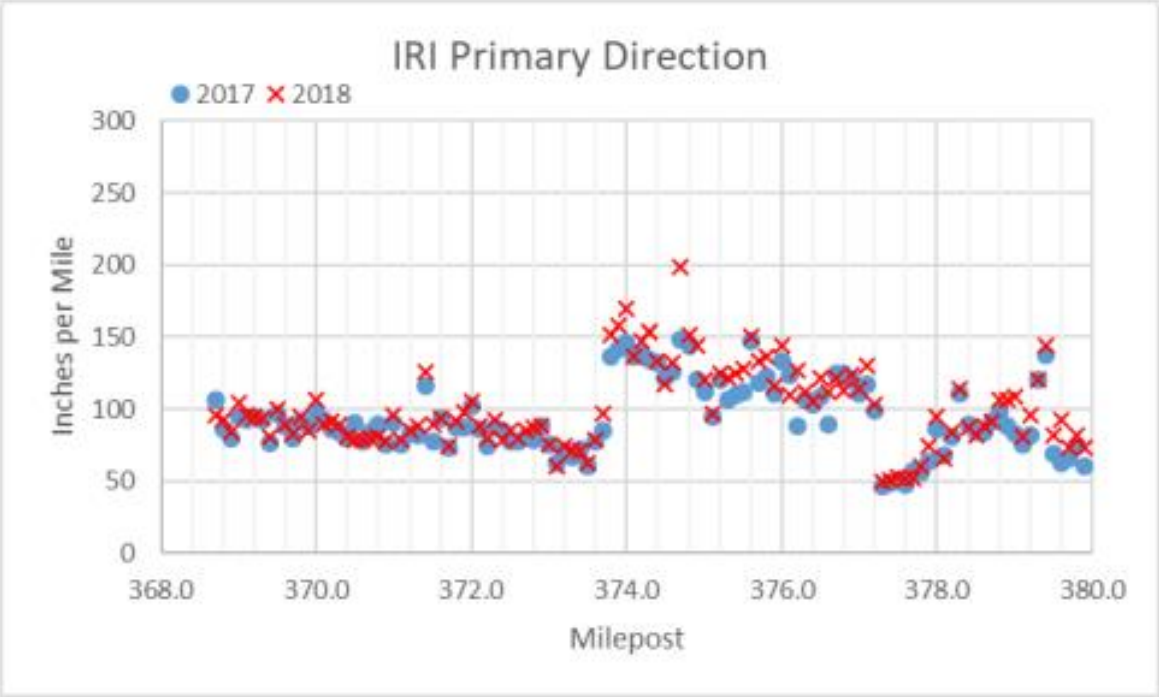
## Summary of Pavement Management Data for the I-70 Project at Genoa

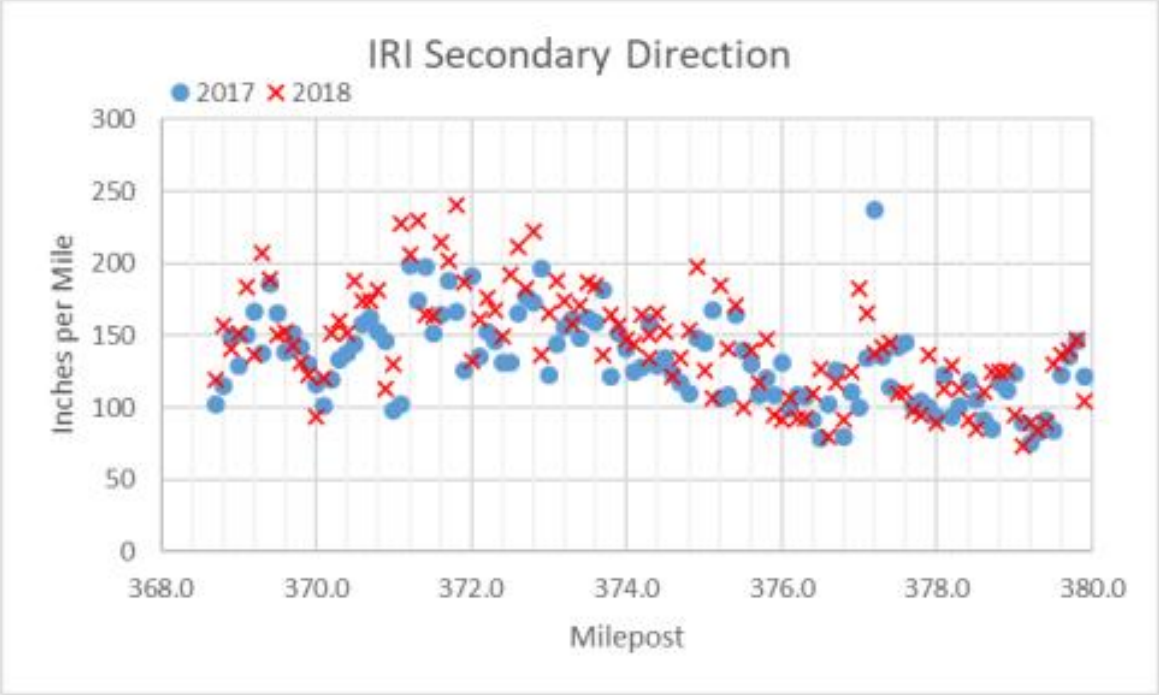



IRI Primary Direction
2008
2009
2010
2011
2012
Inches per Mile
300
250
200
150
100
50
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost


IRI Primary Direction
2013
2014
2015
2016
2017
Inches per Mile
300
250
200
150
100
50
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost


IRI Primary Direction
2017
2018
Inches per Mile
300
250
200
150
100
50
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost


IRI Secondary Direction
2017
2018
Inches per Mile
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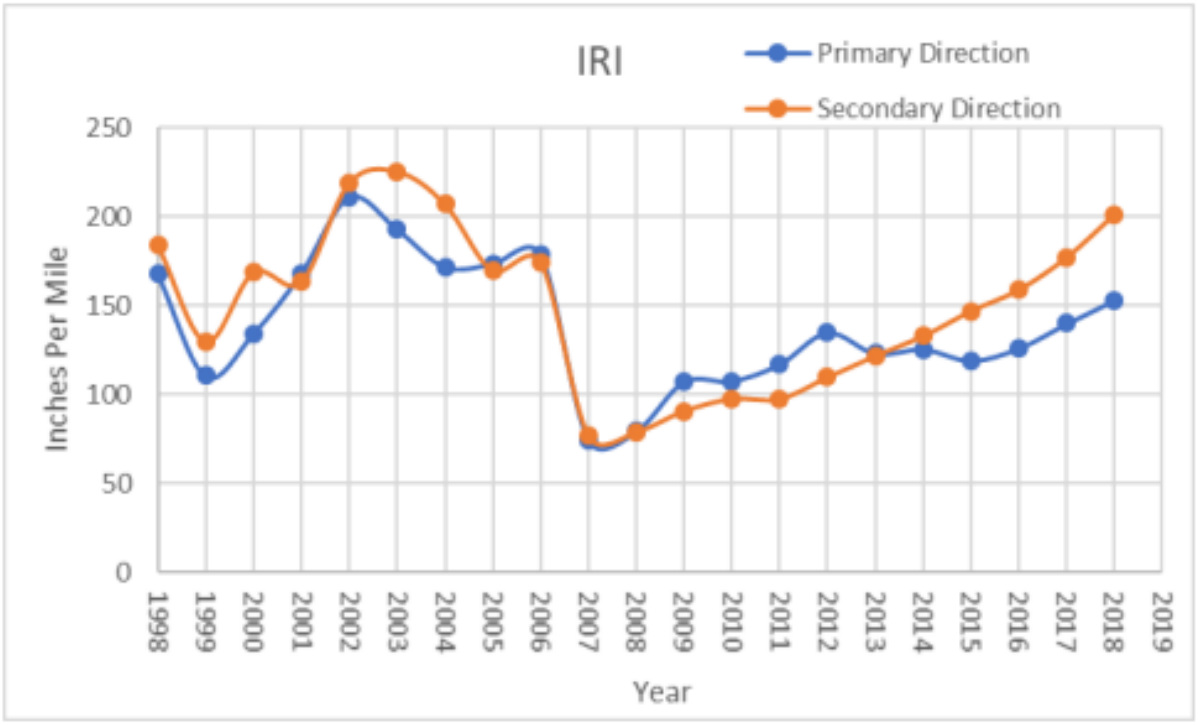
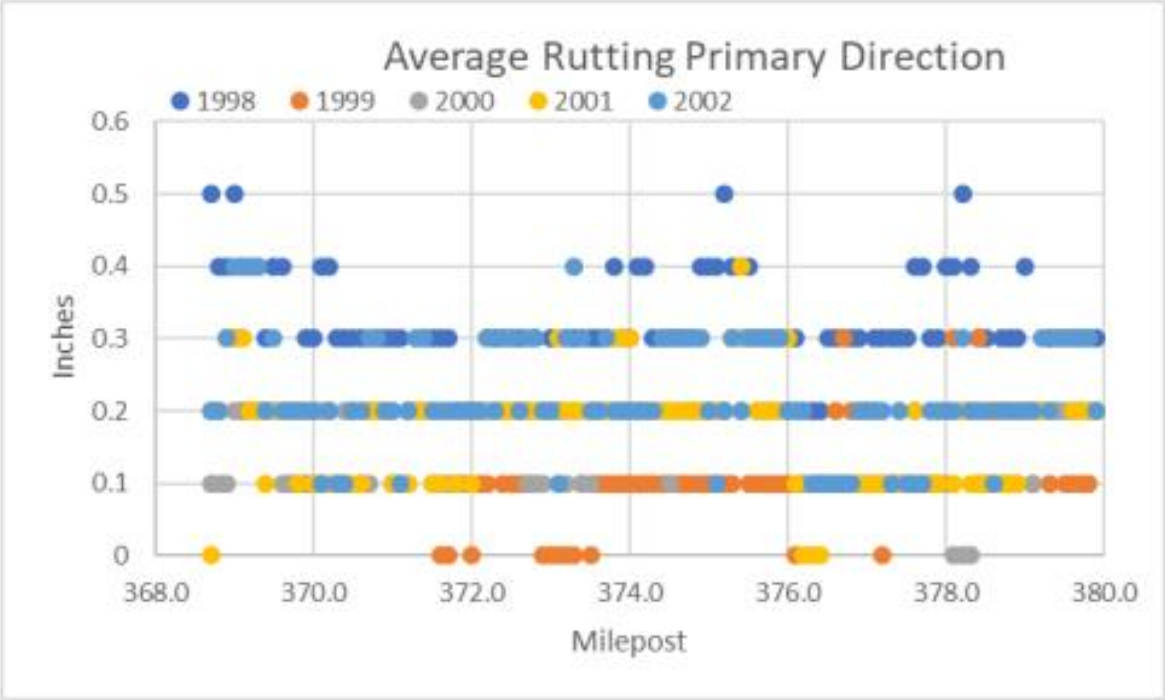
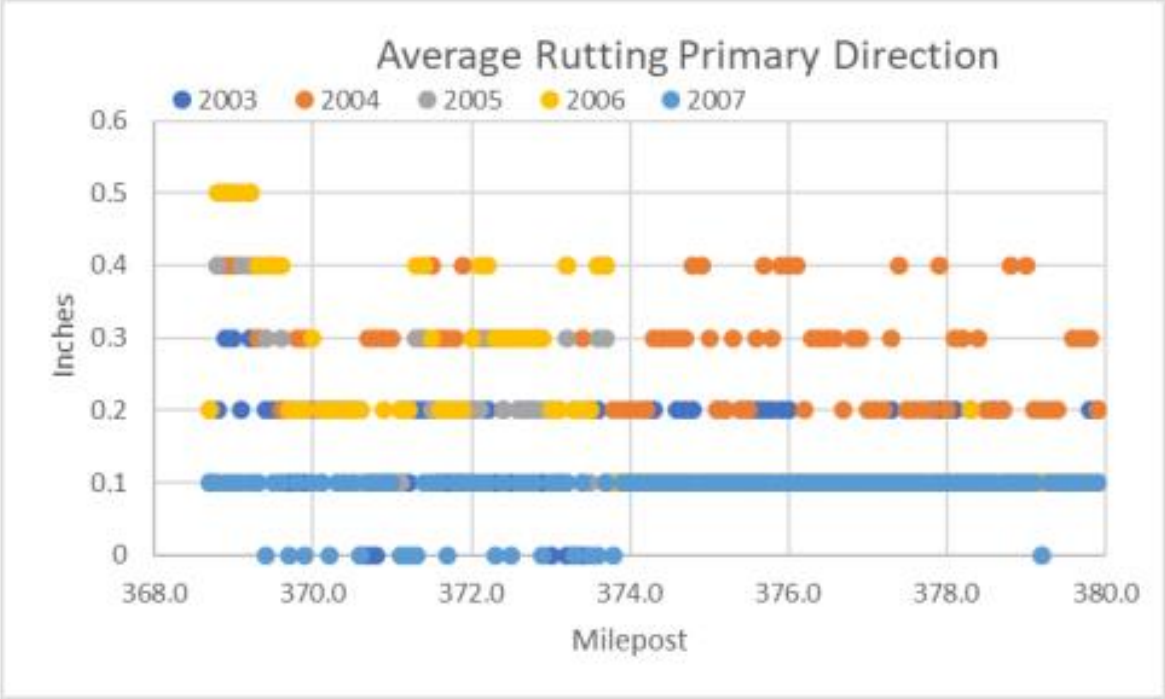
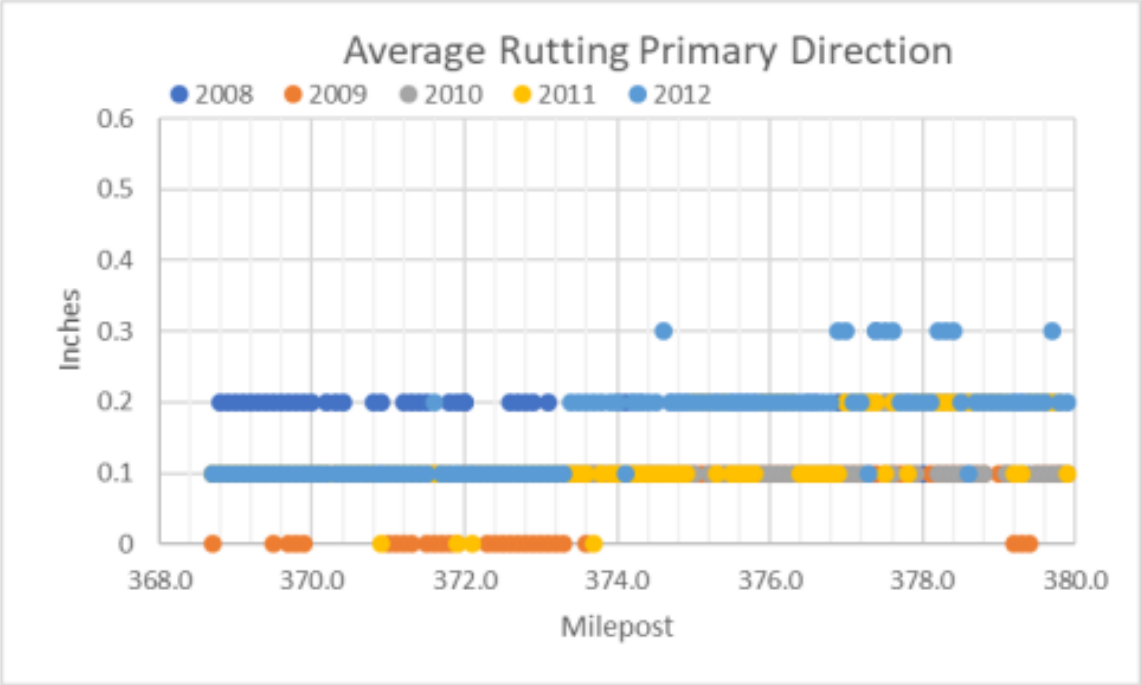
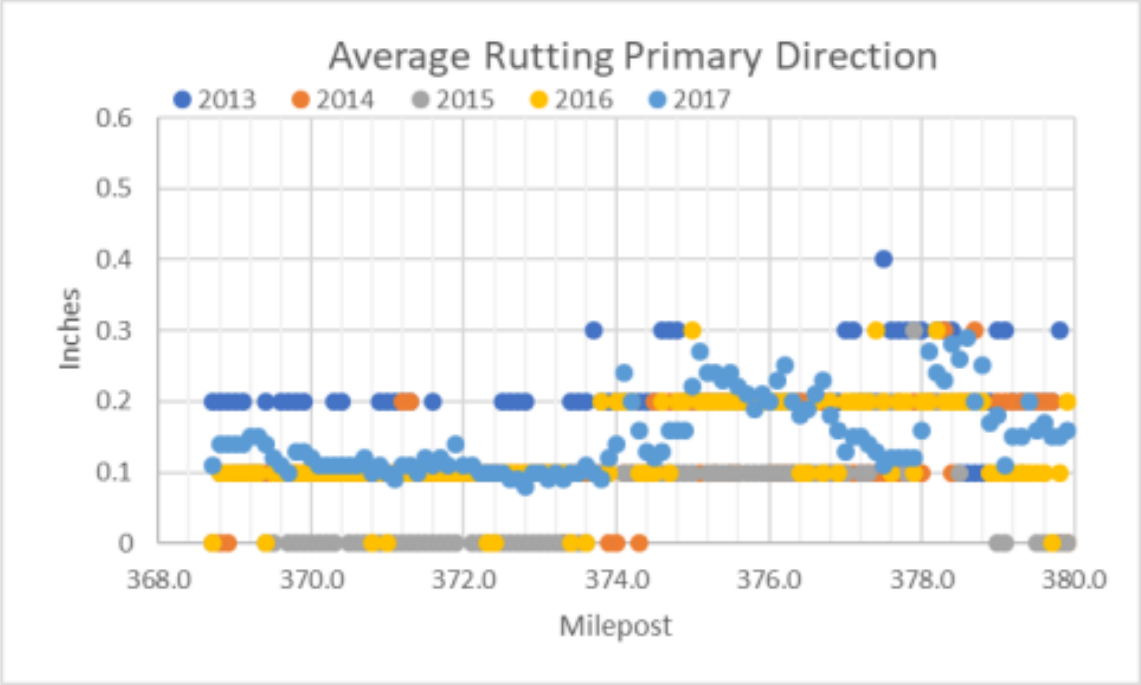
250
200
150
100
50
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

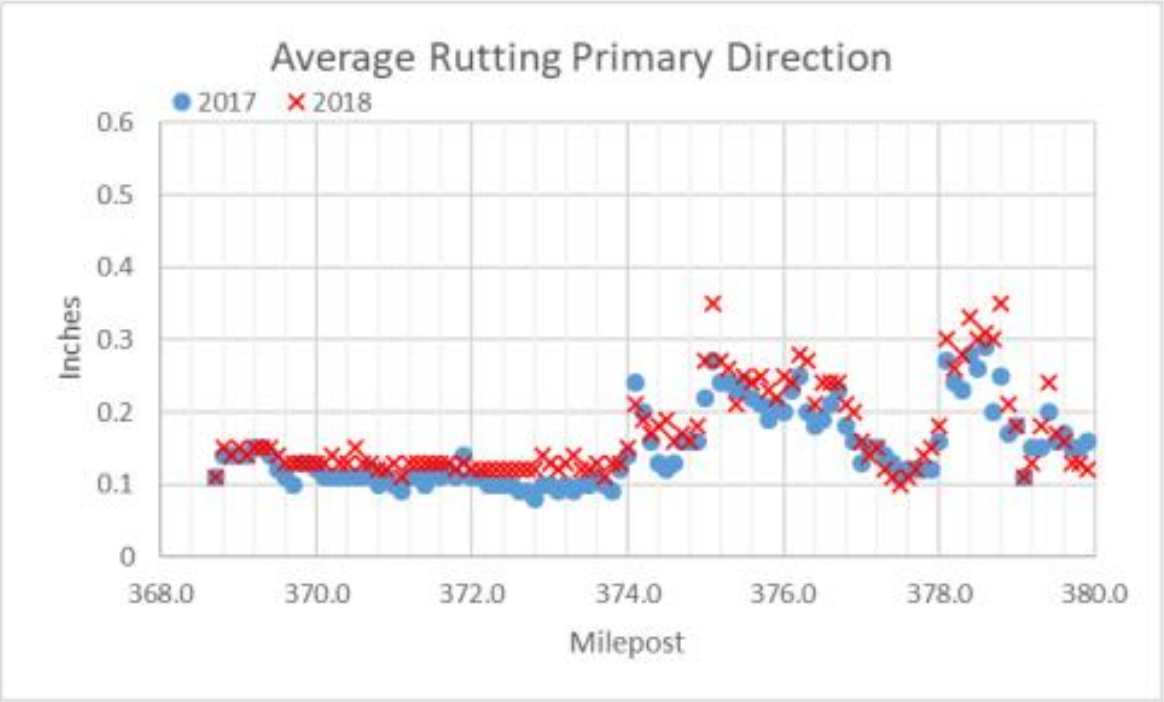

IRI
Primary Direction
Secondary Direction
Inches Per Mile
250
200
150
100
50
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year

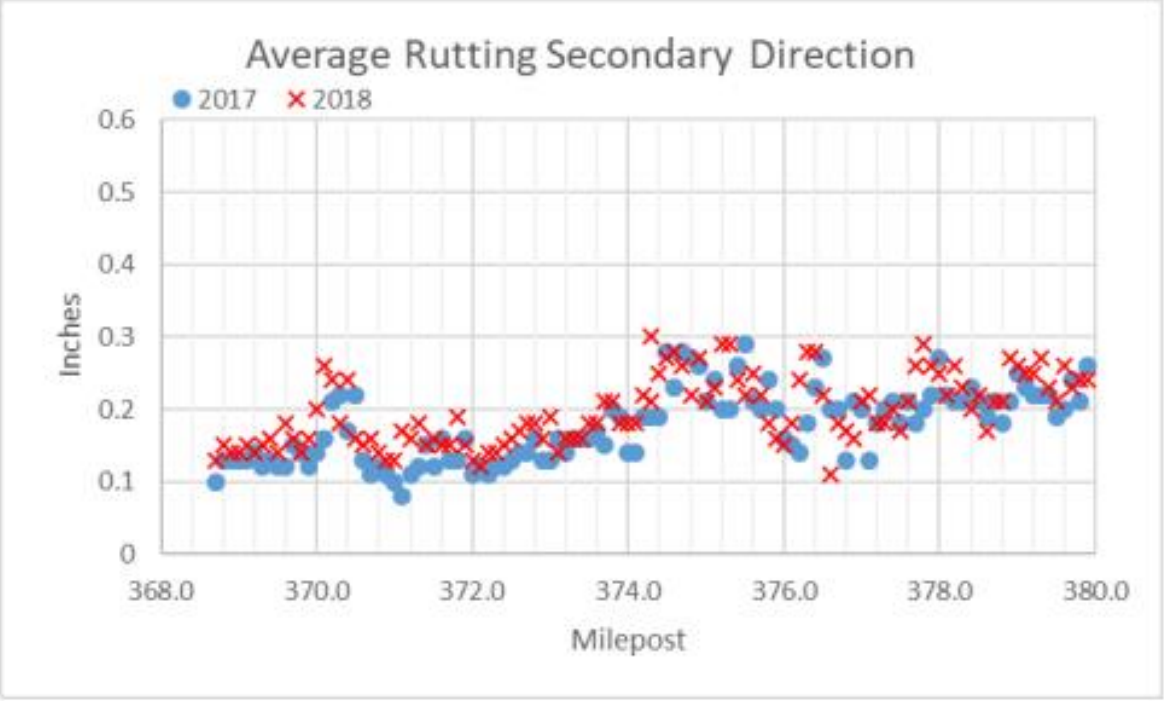

Average Rutting Primary Direction
1998
1999
2000
2001
2002
0.6
0.5
0.4
0.3
0.2
0.1
0
Inches
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

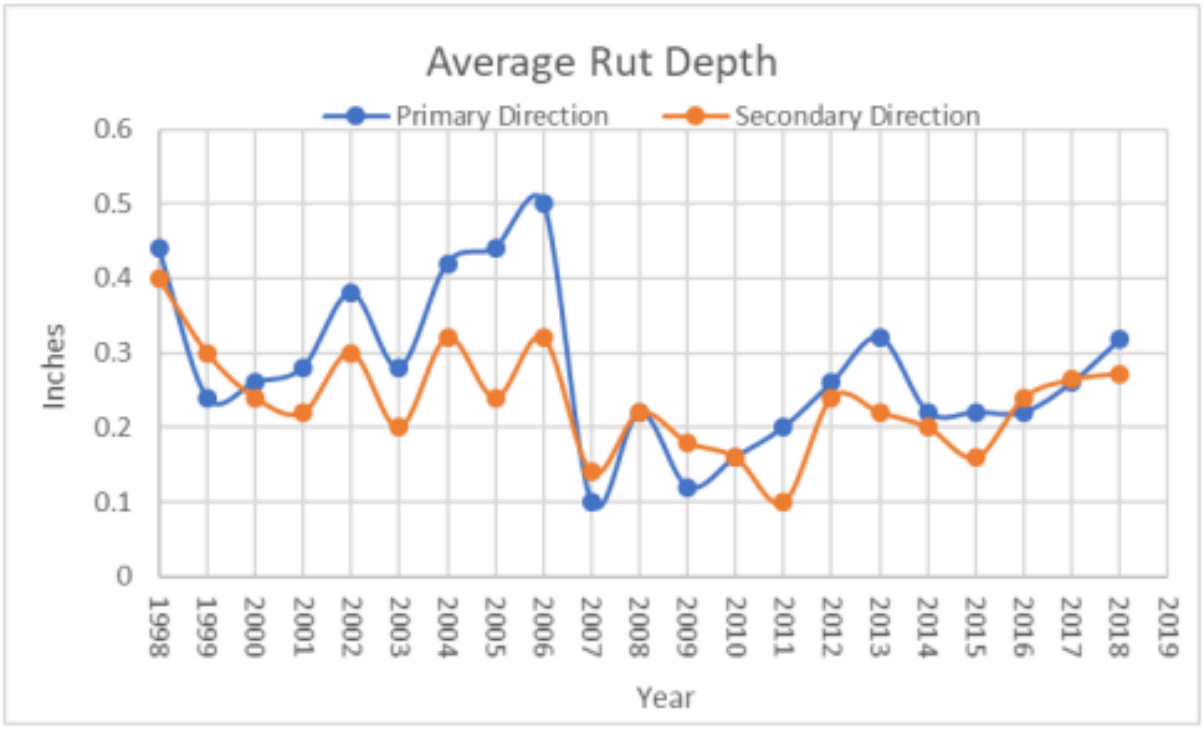

Average Rutting Primary Direction
2003
2004
2005
2006
2007
0.6
0.5
0.4
0.3
0.2
0.1
0
Inches
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

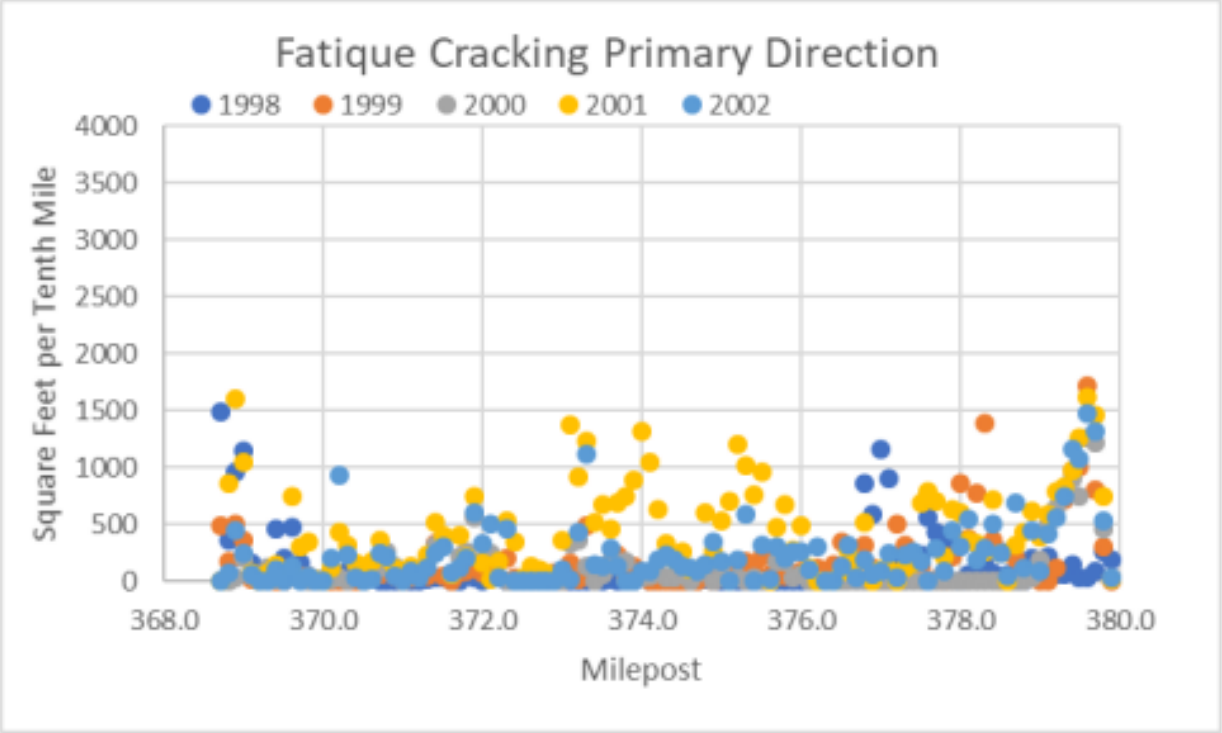

Average Rutting Primary Direction
2008
2009
2010
2011
2012
Inches
0.6
0.5
0.4
0.3
0.2
0.1
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

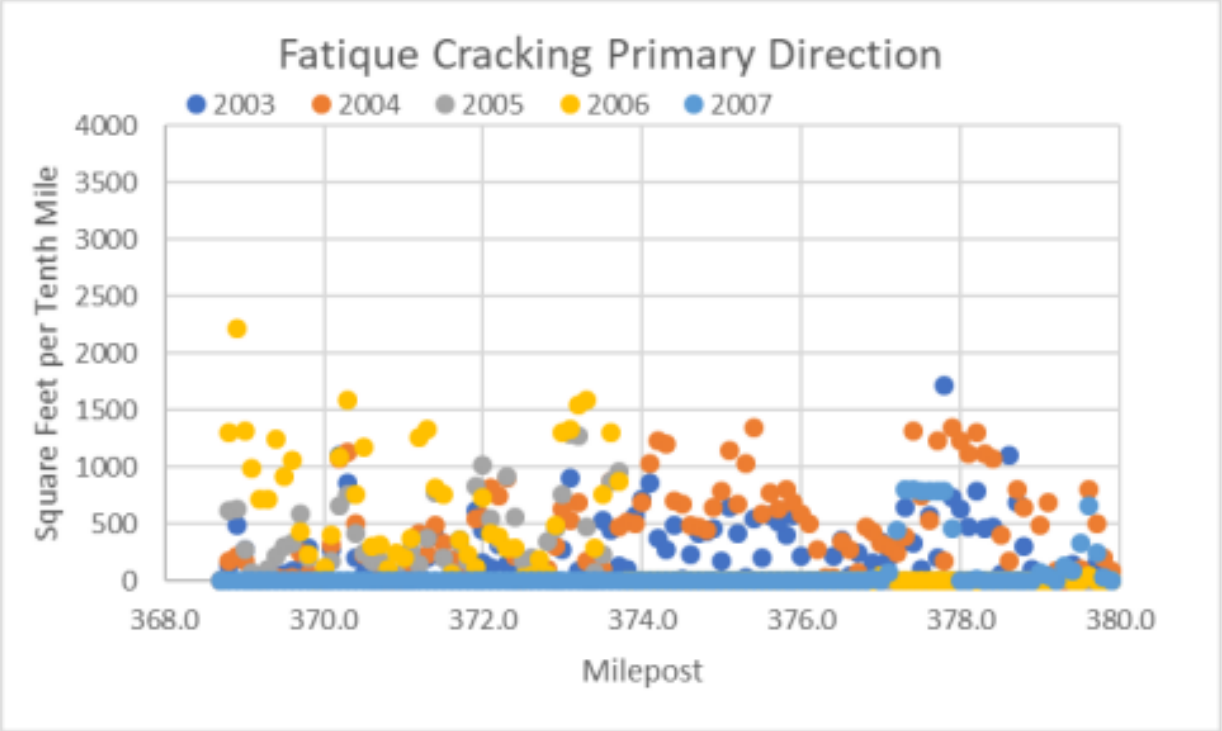

Average Rutting Primary Direction
2013
2014
2015
2016
2017
Inches
0.6
0.5
0.4
0.3
0.2
0.1
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

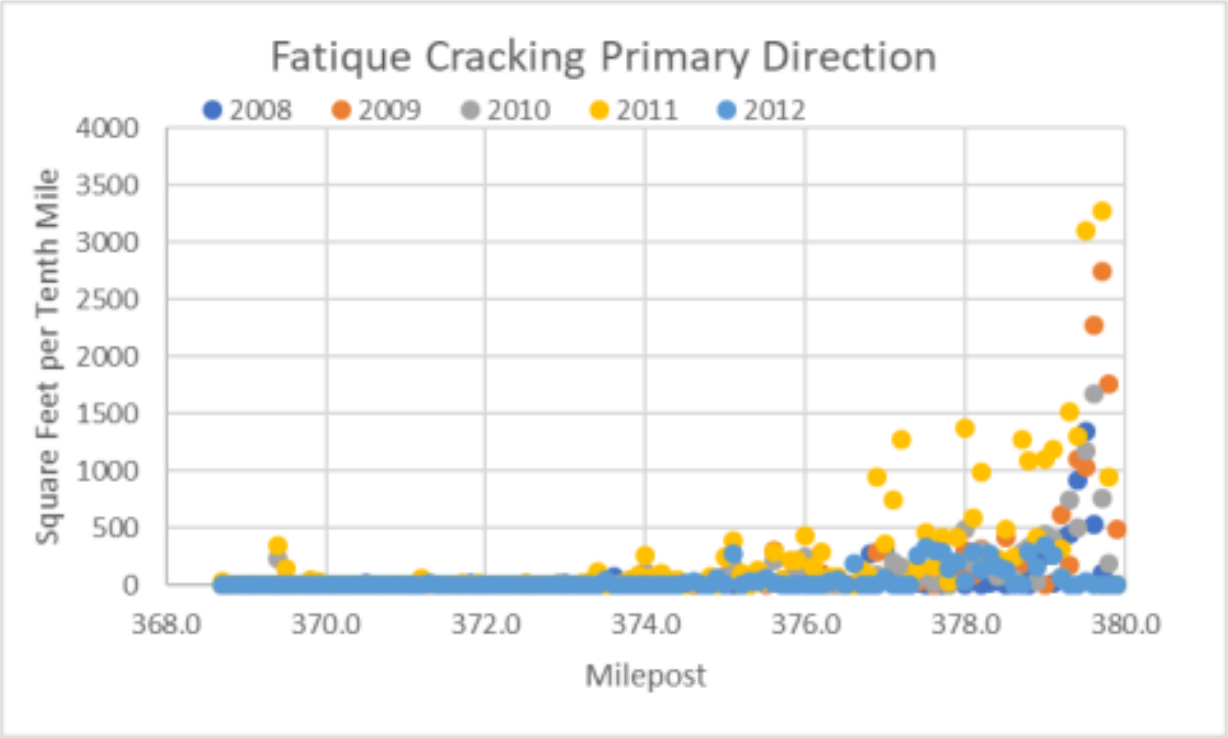

Average Rutting Primary Direction
2017
2018
Inches
0.6
0.5
0.4
0.3
0.2
0.1
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

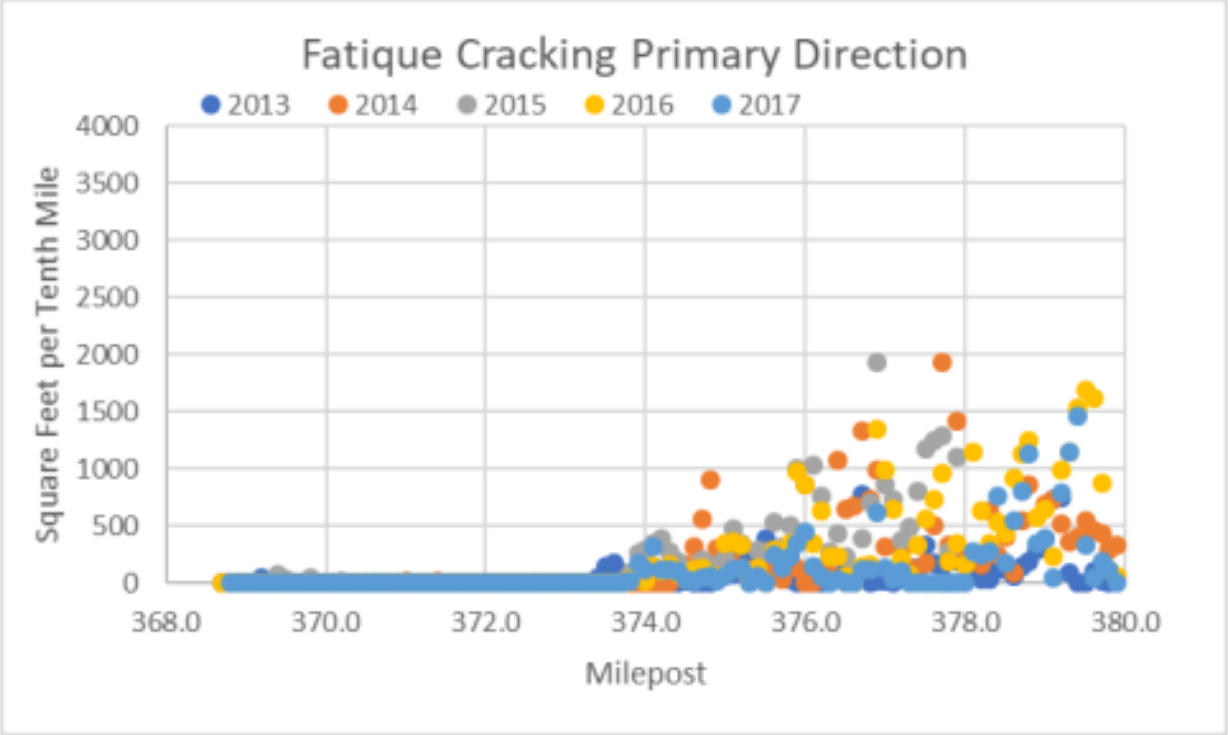

Average Rutting Secondary Direction
2017
2018
Inches
0.6
0.5
0.4
0.3
0.2
0.1
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

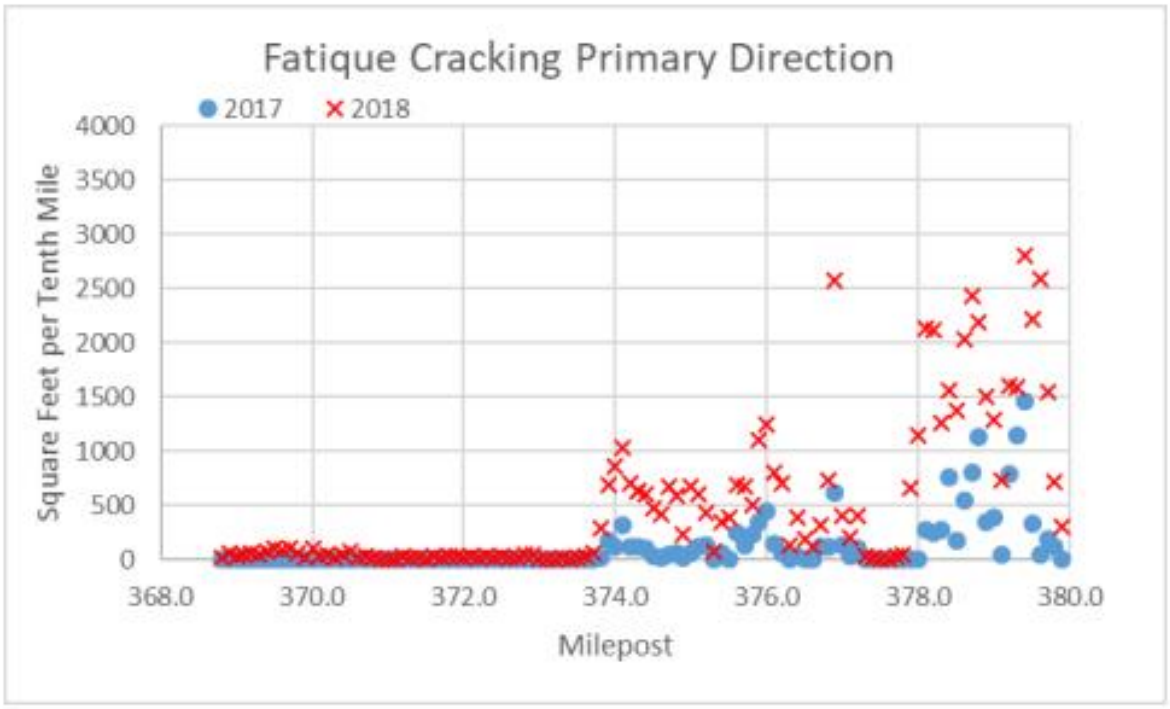

Average Rut Depth
Primary Direction
Secondary Direction
Inches
0.6
0.5
0.4
0.3
0.2
0.1
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year

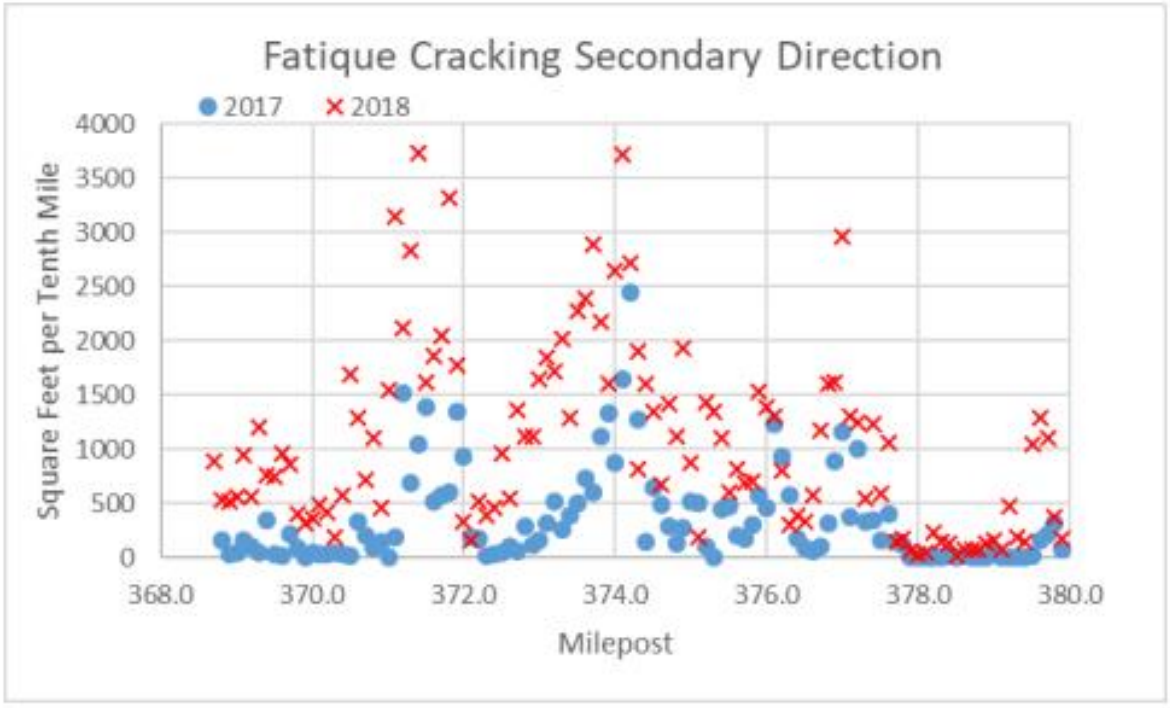

Fatique Cracking Primary Direction
1998
1999
2000
2001
2002
Square Feet per Tenth Mile
4000
3500
3000
2500
2000
1500
1000
500
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

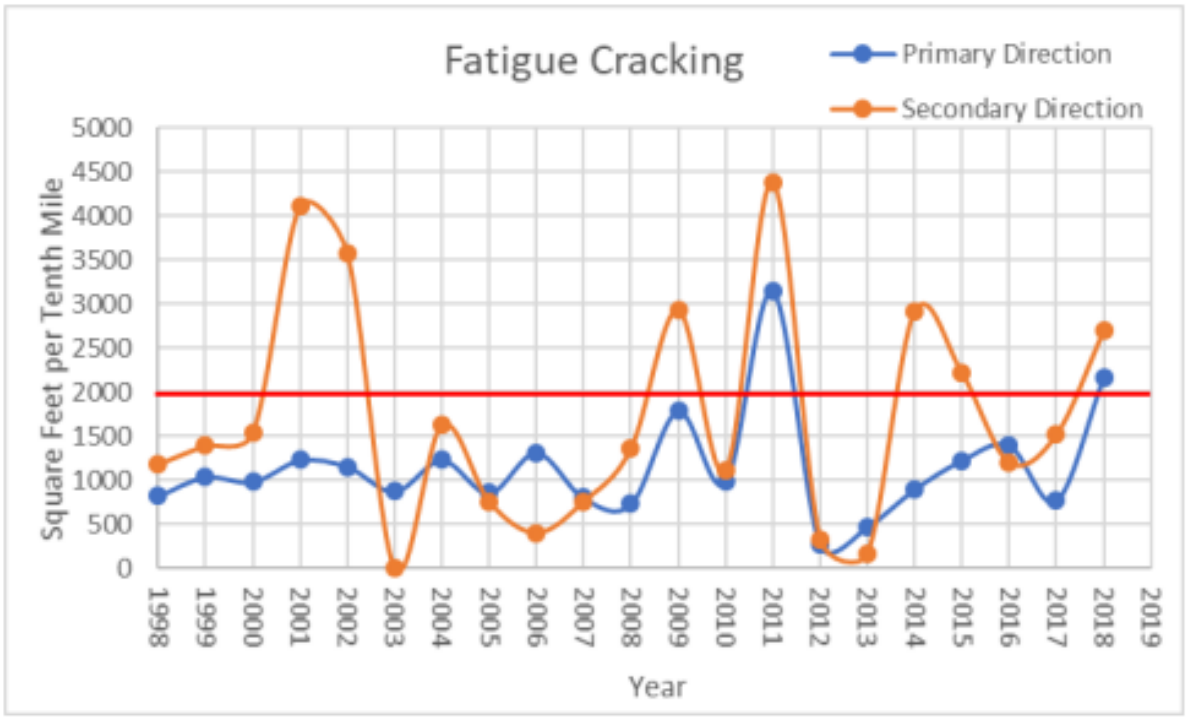

Fatique Cracking Primary Direction
2003
2004
2005
2006
2007
Square Feet per Tenth Mile
4000
3500
3000
2500
2000
1500
1000
500
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

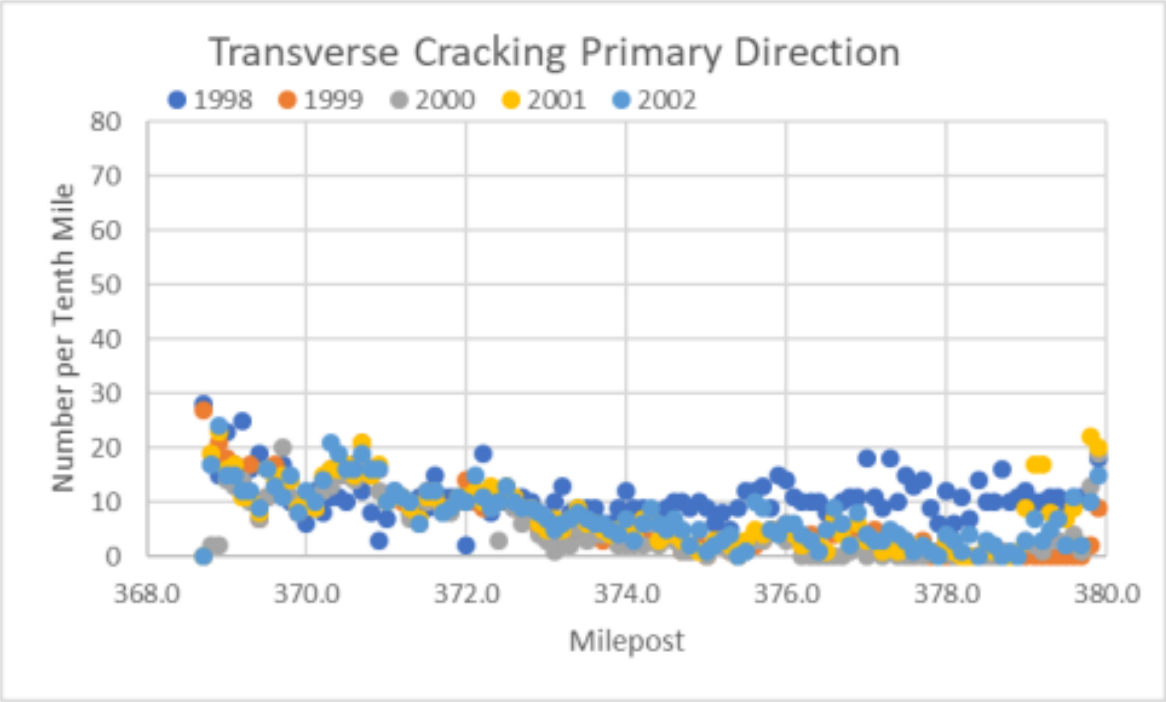

Fatique Cracking Primary Direction
2008
2009
2010
2011
2012
Square Feet per Tenth Mile
4000
3500
3000
2500
2000
1500
1000
500
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

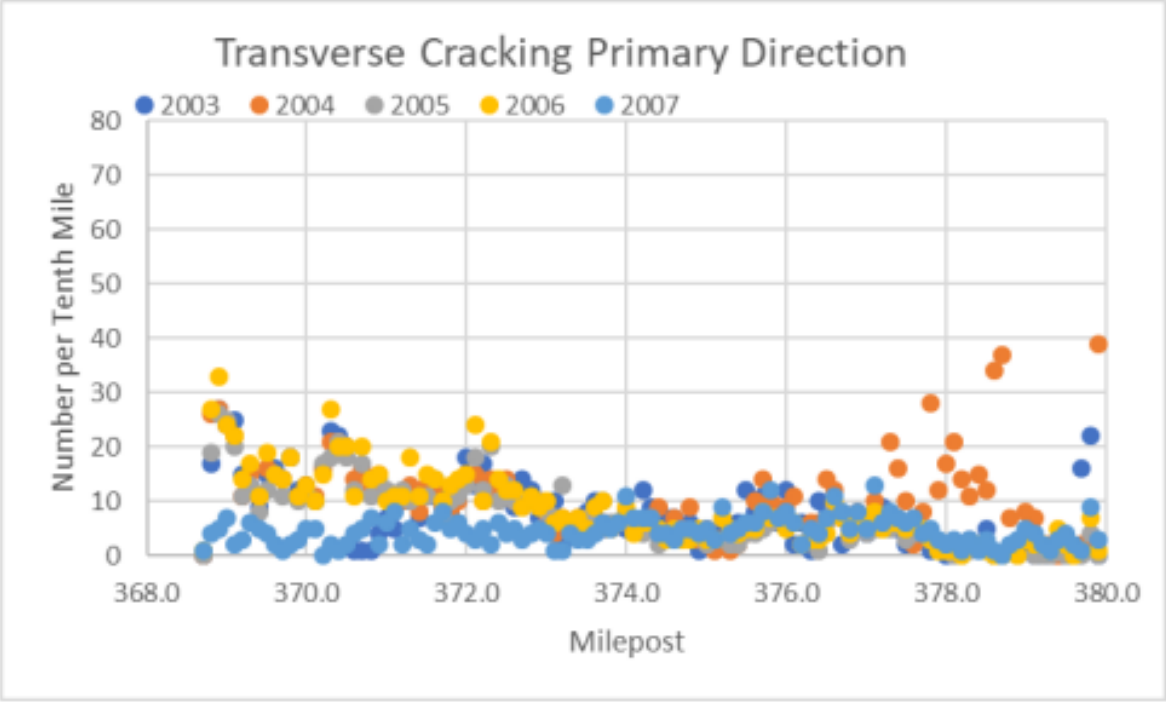

Fatique Cracking Primary Direction
2013
2014
2015
2016
2017
Square Feet per Tenth Mile
4000
3500
3000
2500
2000
1500
1000
500
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

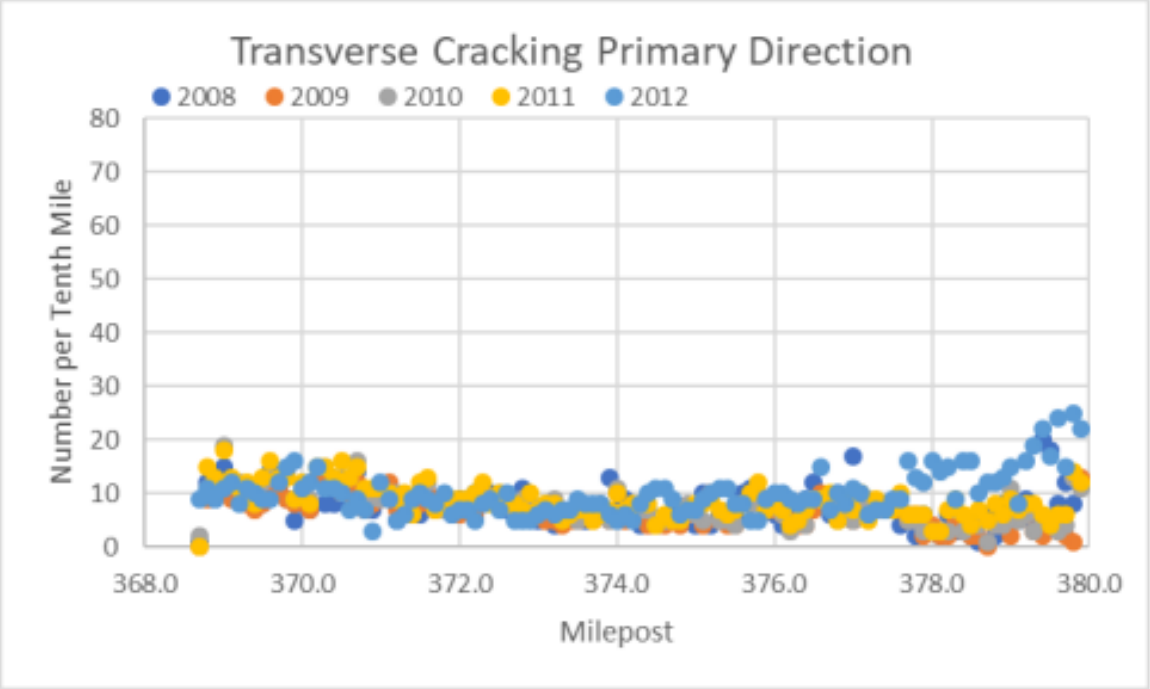

Fatique Cracking Primary Direction
2017
2018
Square Feet per Tenth Mile
4000
3500
3000
2500
2000
1500
1000
500
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

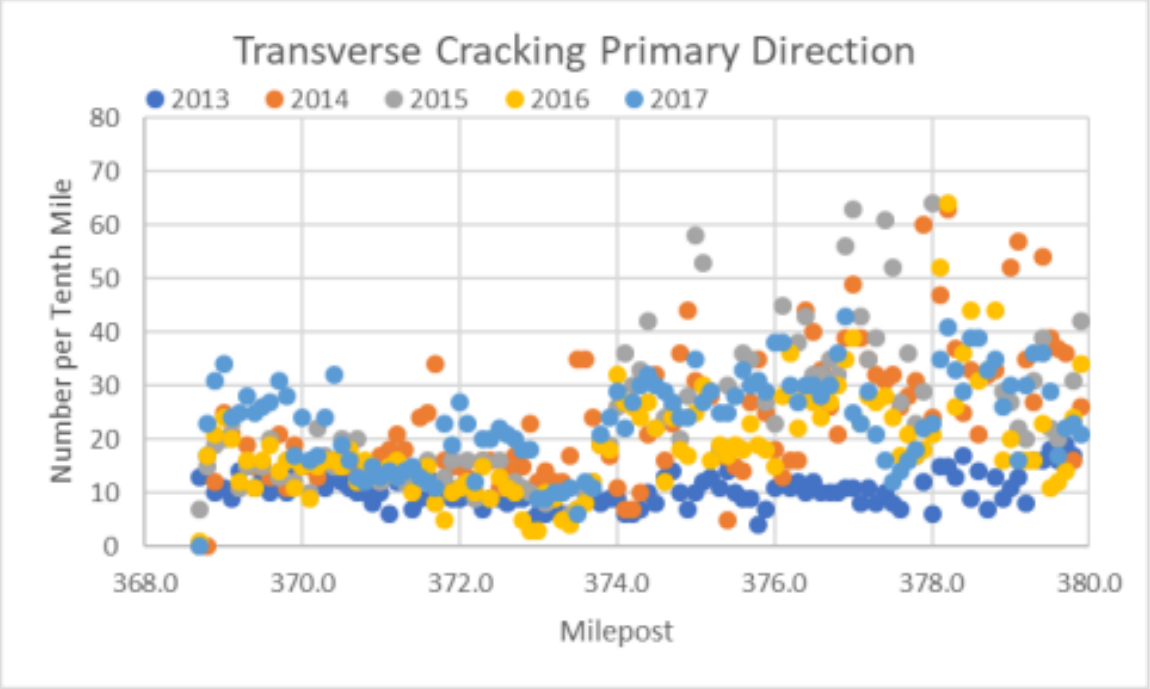

Fatique Cracking Secondary Direction
2017
2018
Square Feet per Tenth Mile
4000
3500
3000
2500
2000
1500
1000
500
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

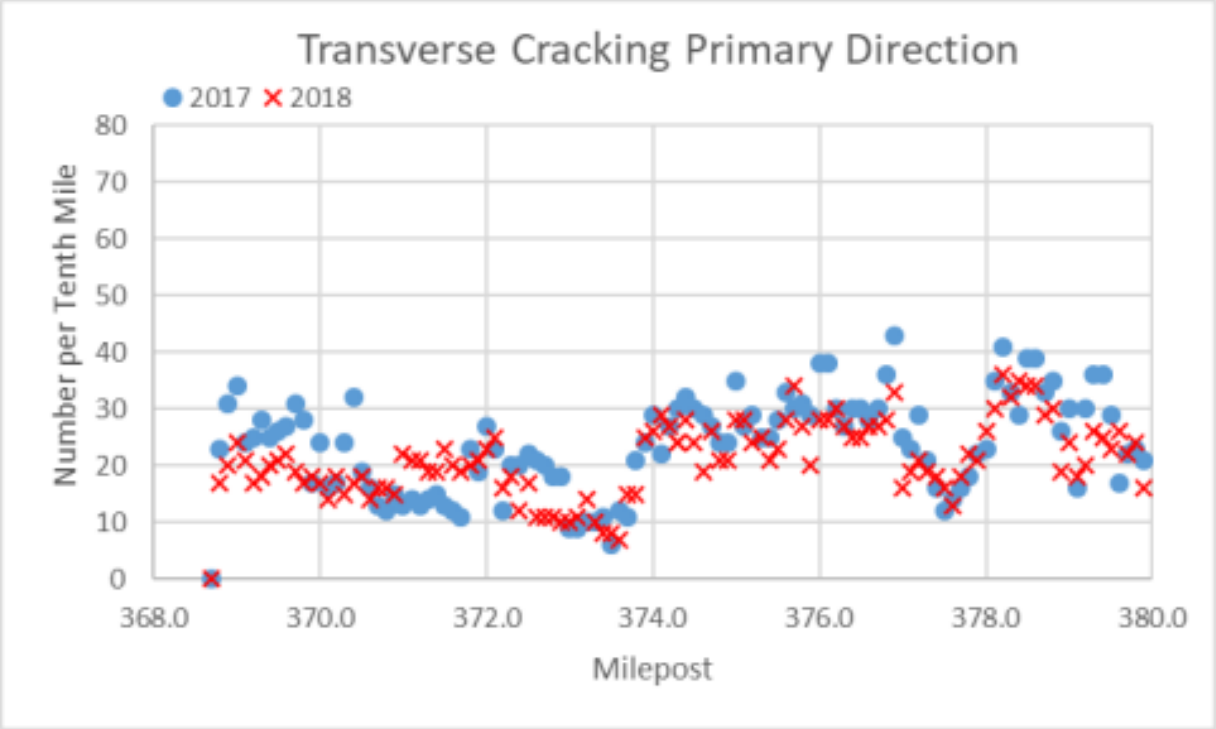

Fatigue Cracking
Primary Direction
Secondary Direction
Square Feet per Tenth Mile
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year

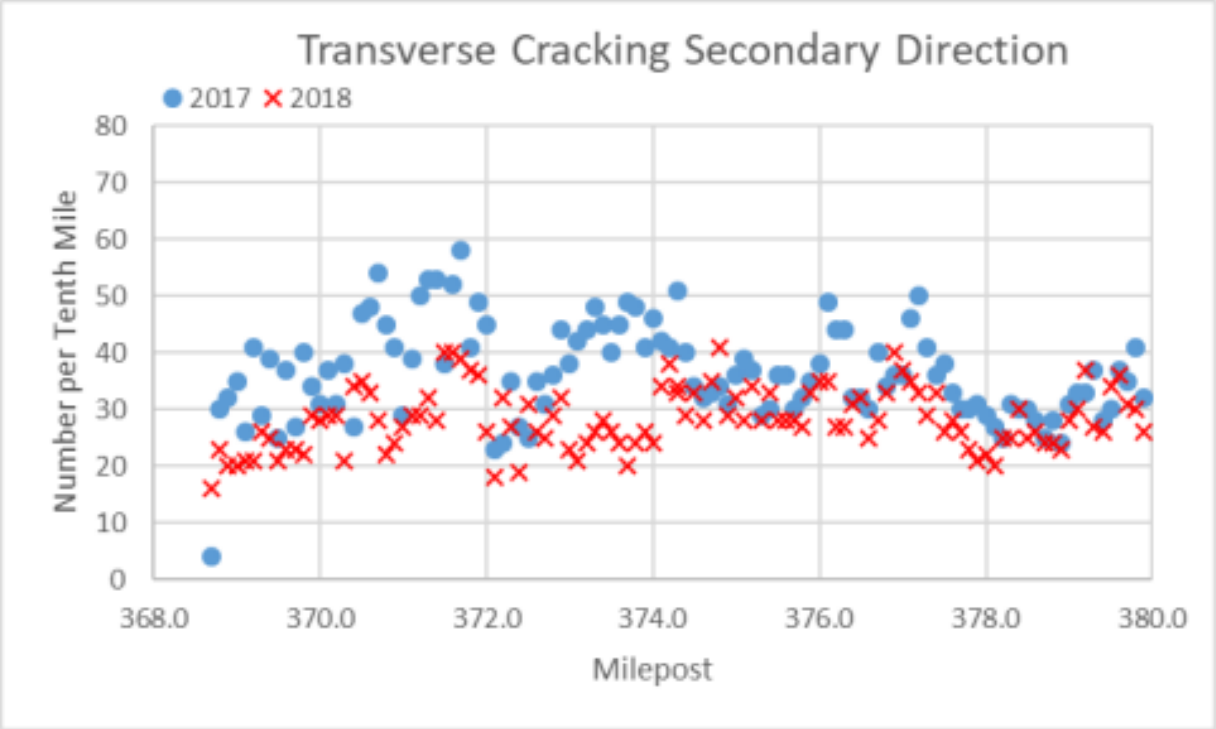

Transverse Cracking Primary Direction
1998
1999
2000
2001
2002
Number per Tenth Mile
80
70
60
50
40
30
20
10
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

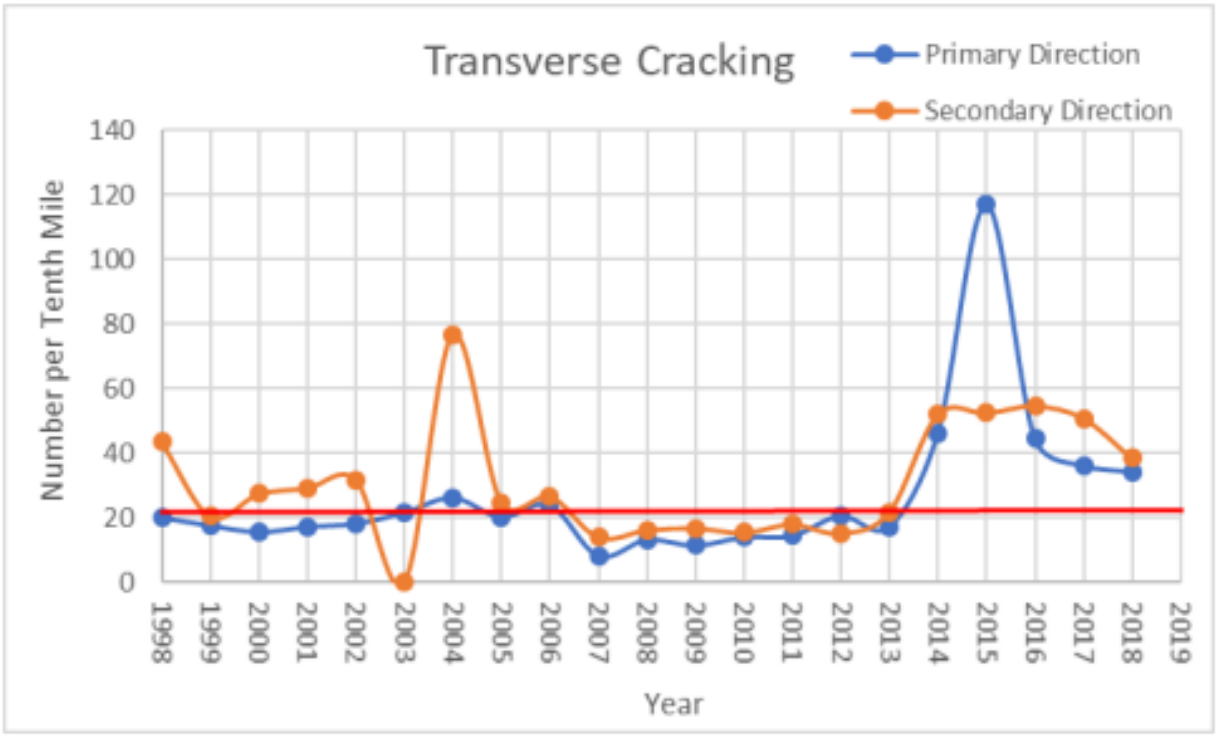

Transverse Cracking Primary Direction
2003
2004
2005
2006
2007
Number per Tenth Mile
80
70
60
50
40
30
20
10
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

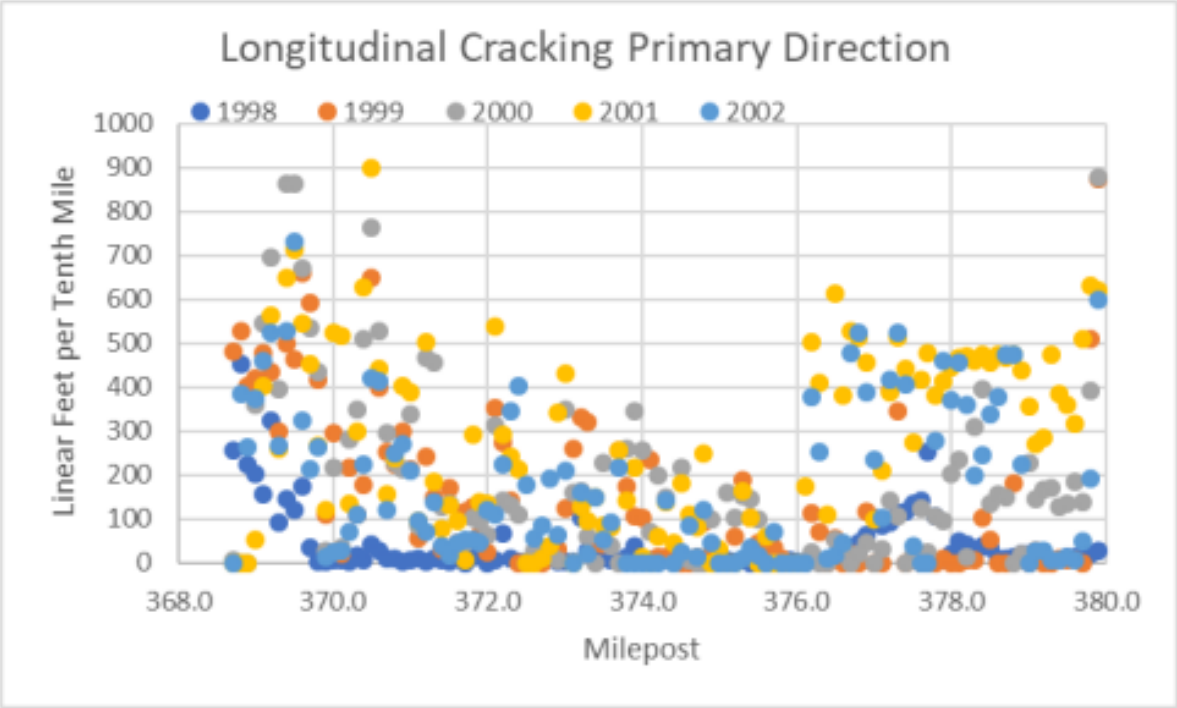

Transverse Cracking Primary Direction
2008
2009
2010
2011
2012
Number per Tenth Mile
80
70
60
50
40
30
20
10
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

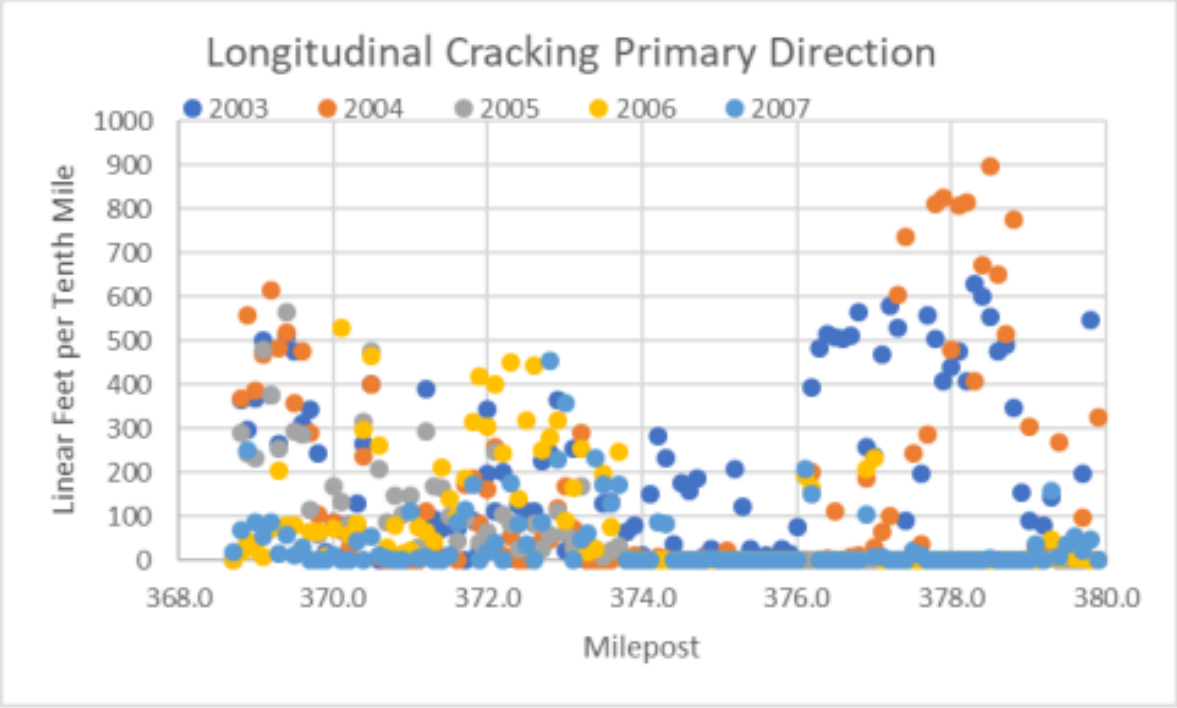

Transverse Cracking Primary Direction
2013
2014
2015
2016
2017
Number per Tenth Mile
80
70
60
50
40
30
20
10
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

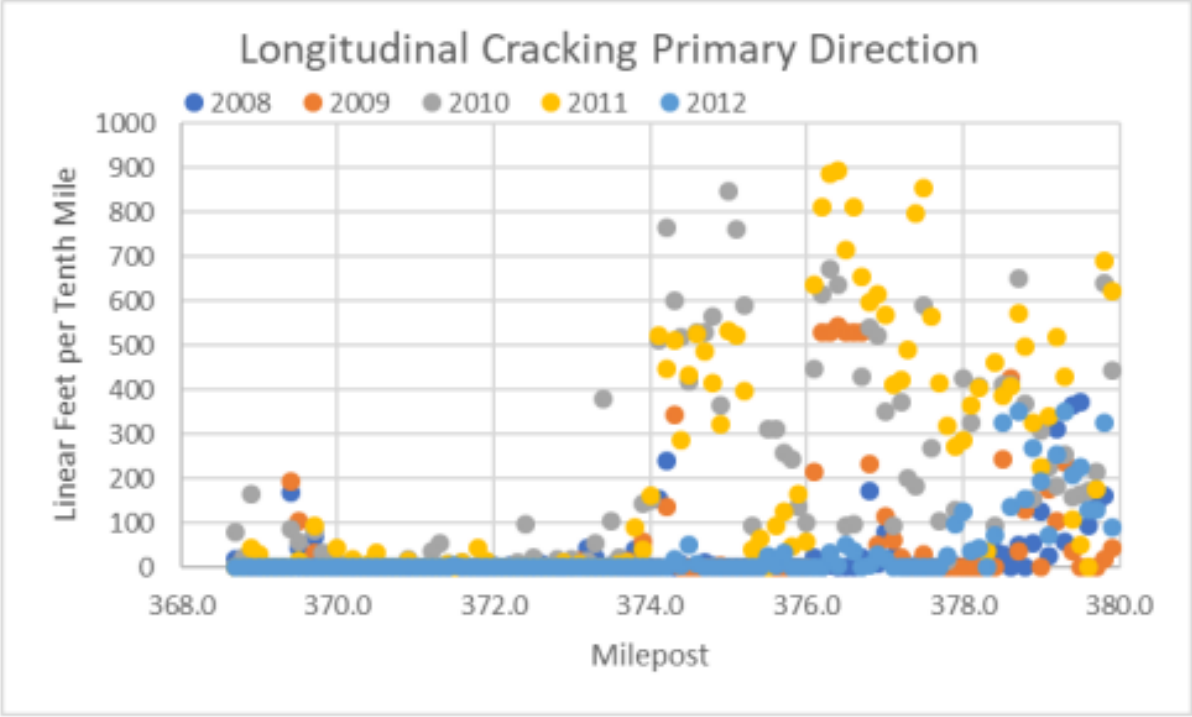

Transverse Cracking Primary Direction
2017
2018
Number per Tenth Mile
0
10
20
30
40
50
60
70
80
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

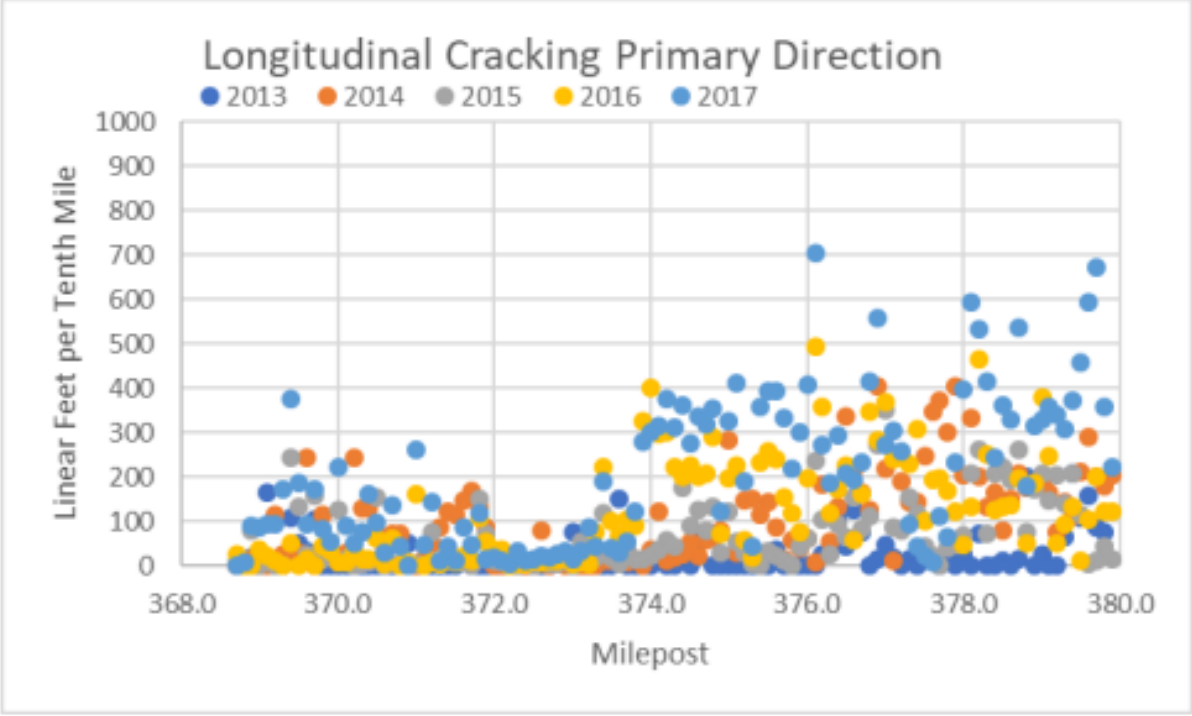

Transverse Cracking Secondary Direction
2017
2018
Number per Tenth Mile
0
10
20
30
40
50
60
70
80
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

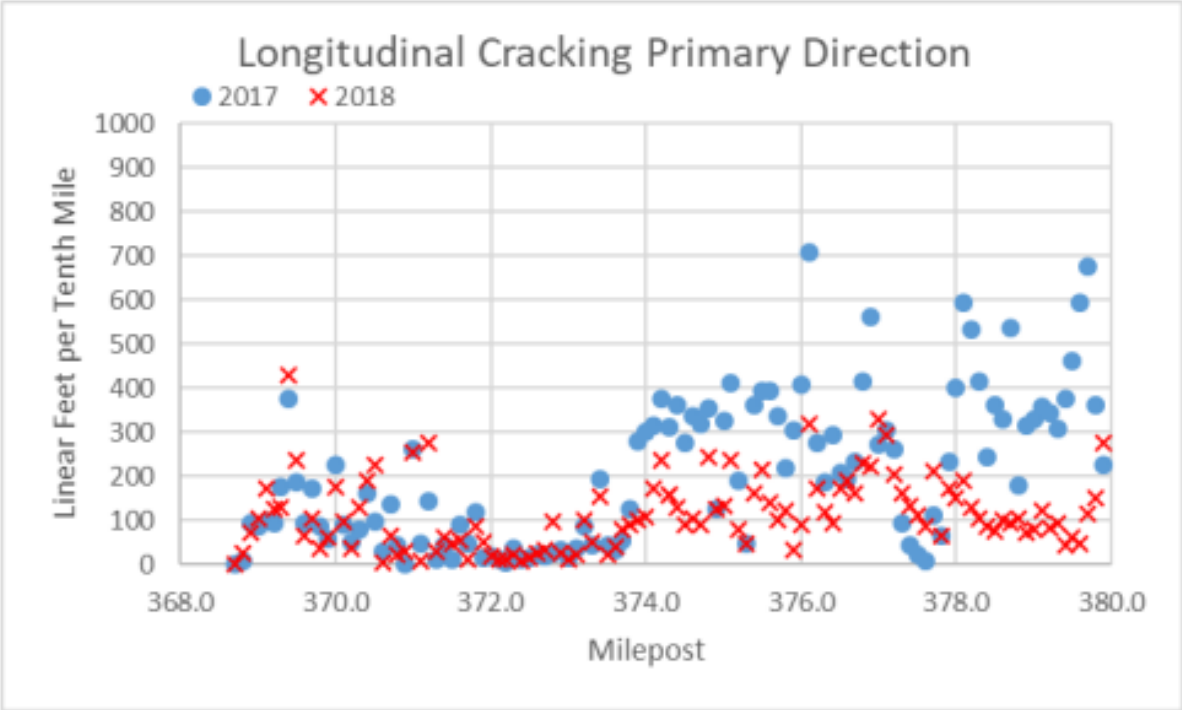

Transverse Cracking
Primary Direction
Secondary Direction
Number per Tenth Mile
140
120
100
80
60
40
20
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year

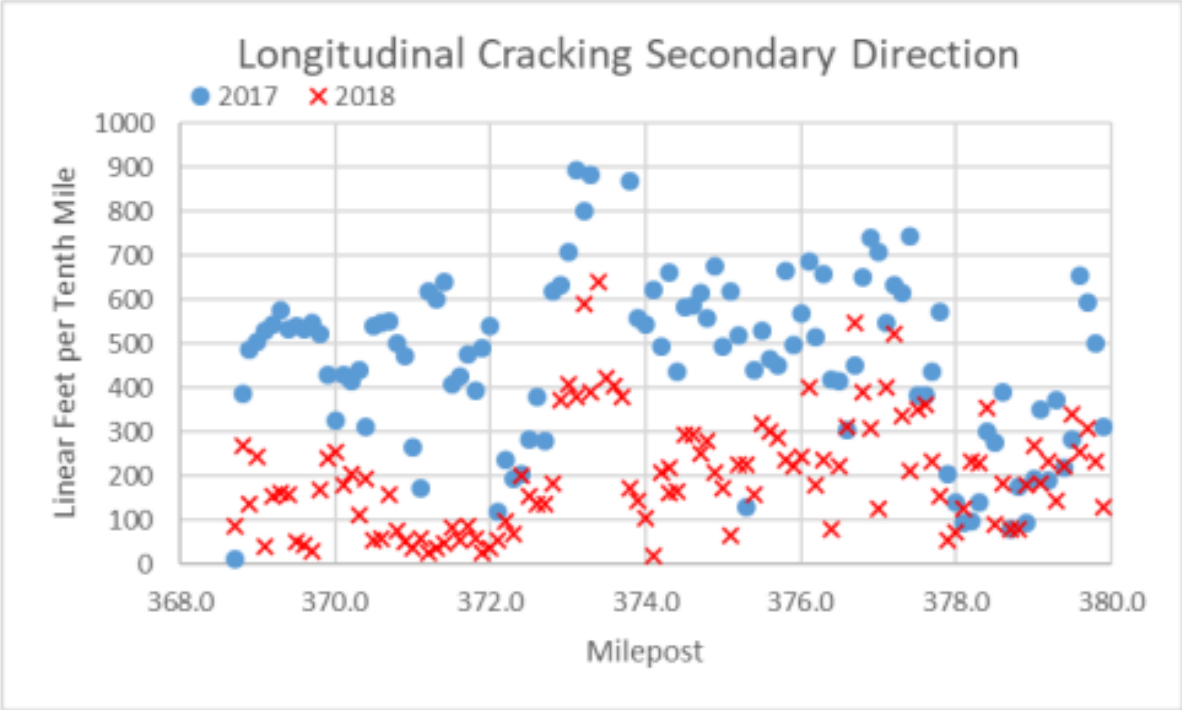

Longitudinal Cracking Primary Direction
1998
1999
2000
2001
2002
Linear Feet per Tenth Mile
1000
900
800
700
600
500
400
300
200
100
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost

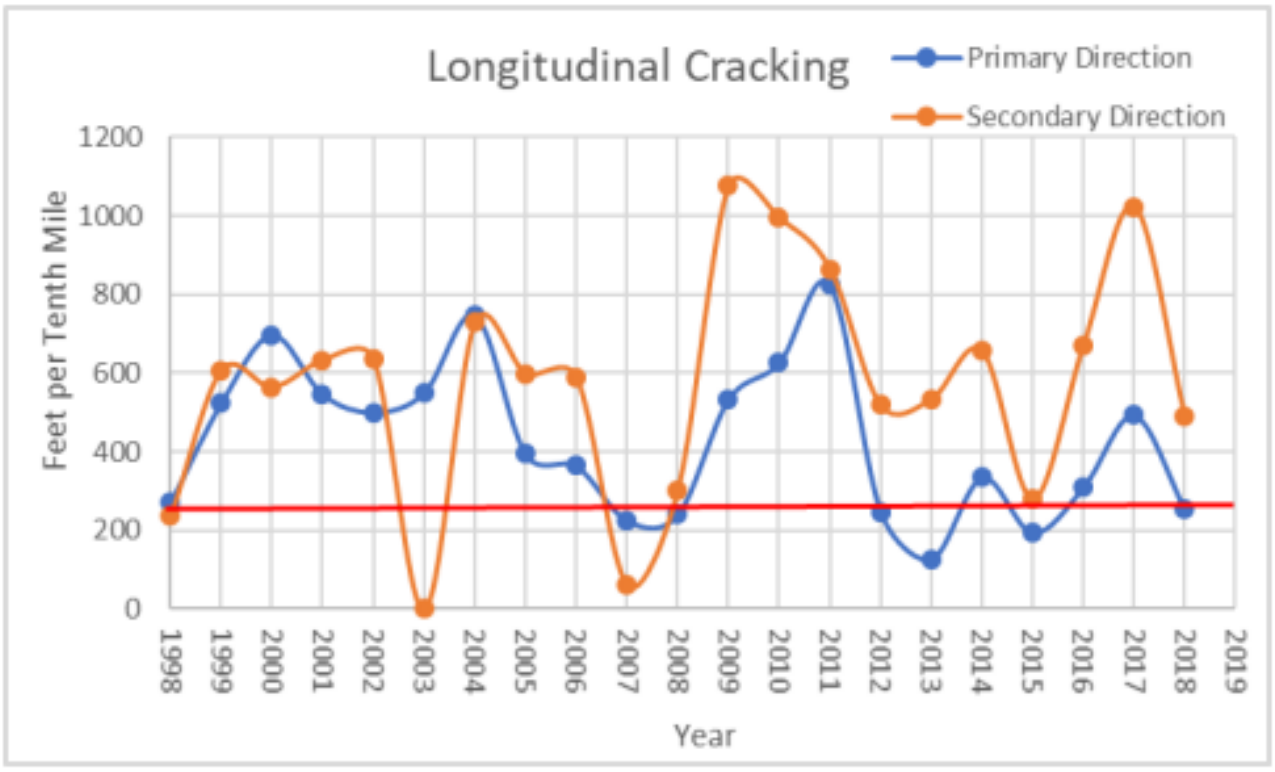

Longitudinal Cracking Primary Direction
2003
2004
2005
2006
2007
Linear Feet per Tenth Mile
1000
900
800
700
600
500
400
300
200
100
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost


Longitudinal Cracking Primary Direction
2008
2009
2010
2011
2012
Linear Feet per Tenth Mile
1000
900
800
700
600
500
400
300
200
100
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost


Longitudinal Cracking Primary Direction
2013
2014
2015
2016
2017
Linear Feet per Tenth Mile
1000
900
800
700
600
500
400
300
200
100
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost


Longitudinal Cracking Primary Direction
2017
2018
Linear Feet per Tenth Mile
1000
900
800
700
600
500
400
300
200
100
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost


Longitudinal Cracking Secondary Direction
2017
2018
Linear Feet per Tenth Mile
1000
900
800
700
600
500
400
300
200
100
0
368.0
370.0
372.0
374.0
376.0
378.0
380.0
Milepost


Longitudinal Cracking
Primary Direction
Secondary Direction
Feet per Tenth Mile
1200
1000
800
600
400
200
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year

# Appendix E CDOT Disposition Information

## E.1 VE Proposal and Design Comments Disposition Information

***Rough Draft #1: 9/19/19, SDH***

***VE Proposal 2-Optimized Pavement Design Idea:***

We have performed site specific designs analyzing the proposed change. Performing site specific designs, many of the site designs were already designed to CDOTs minimum Design Life standard of 27 years. Unless it is desirable to change thickness of concrete on a regular basis throughout the project limits, and differing in both directions also, we recommend utilizing the originally proposed design thickness. It is our opinion that there will be negligible cost savings switching thicknesses on a regular basis while increasing CDOTs risk for construction and design related deficiencies.

*Notes on incorrect design items which are consistent through many of the supplied designs associated with the VE Proposals:*

1. The Consultant designed pavement section is not an accurate portrayal of the project's unique traits and underestimates the variability of the underlying soil and pavement structures. Utilization of this non-site specific design will not yield consistent performance results across the project.
2. Does not follow limiting strength criteria as set forth by Figures 5.2 and 5.3 of PDM. The Consultant has overestimated the strength of the underlying soils by not following these limiting criteria.
3. Existing Construction date is not site specific and the May 2006 date does not accurately reflect the entire projects limits. There are parts of the project which the last project was older and shoulder areas which are significantly older.
4. The Pavement Construction Date is listed as May, with the Consultant's reasoning being the Pavement Design Manual Section 7.6.1.2. This PDM section actually states that "if the actual months of construction is unknown the month of May should be used. The Mechanistic Empirical Pavement Design Guide Manual of Practice states that the Construction Month should be listed as "the month and Year that the HMA or PCC has been placed to cover the unbound layers." Considering that May seems like a very early time of the year to have the pavement completed, we think July is a much more reasonable month to utilize for design purposes.
5. The PCC Layers were characterized using a Level 3 Lawson mix which is the least accurate test information for this material. Per PDM Table 2.8, Interstates require the use of Level 1 Designs for materials. We do not subscribe to changing any of the properties of the Level 1 database mixes as these are tested values.
6. The pavement designs by the Consultant modeled the imported aggregate base course material as subgrade. We would contend that imported aggregate base coarse should be modeled as Unbound Base in the program as it is not a native material for the project.
7. Consultant's Erodibility Index appears to be incorrect for overlaying existing HMA
8. The consultant's typical section which utilizes 8" of HMA existing does not account for the stripped layers in the existing HMA and overestimates the pavement's available section strength and stability. Some areas based upon the location and extent of the stripped HMA have only 1.5" of intact pavement without distress in the HMA core.

***VE Proposal 3-Optimized Milling:***

Additional research is being performed with additional cores and soils being collected on the shoulders. Currently, it appears based upon As-Builts from older projects, the shoulders may be at a significantly reduced thickness compared to the through lane pavement. Further research is required prior to deciding on how to proceed.

***VE Proposal 4- Use Widened Lanes Idea:***

We have evaluated the proposal to widen lanes, in several ways, to determine the feasibility and risk associated with this change. Currently in the Mechanistic Empirical Pavement Design Guide Manual of practice, it states *"Wider slabs can be used for outside truck lanes to move the wheel path away from the edges and corner of the slab to reduce stresses in these areas. As little as a one foot widening has a significant effect. However, the potential for longitudinal cracking is increased with wider slabs, especially in thinner slabs (<10 inches), although AASTHO Ware Pavement ME Design does not predict longitudinal cracking."* In conjunction with this and International Journal of Pavement Research and Technology 11(2018) *Longitudinal Cracking of Jointed Plain Concrete Pavements in Louisiana: Field Investigation and Numerical Simulation* by Danny Xiao and Zhong Wu, and IHRB Project TR-700 *Prevention of Longitudinal Cracking in Iowa Widened Concrete Pavement* (June 2018) for Iowa Highway Research Board Iowa DOT by Iowa State University (Specifically analysis between Pages 110-121), we feel that the risk of significant longitudinal cracking by utilizing widening of the slab in conjunction with thinning of the PCCP slab in Pavement ME is detrimental to the long term performance of the pavement. We propose to not allow utilization of Pavement ME and widening the slab as a method for decreasing the thickness of PCCP, as the primary expected failure mode (Longitudinal Cracking) is not currently feasible for evaluation using the Pavement ME program and could put CDOT at substantial risk for potential early deterioration from longitudinal cracking.

Excerpts from *Longitudinal Cracking of Jointed Plain Concrete Pavements in Louisiana: Field Investigation and Numerical Simulation;*

*"3.3. Widened slabs and tied concrete shoulders*
*Fig. 5 shows different types of cracking grouped by slab width and shoulder type. Two statistics are presented: (1) the total length to accommodate the common practice in pavement management systems, and (2) the cracked slabs in percentage to suit for the current mechanistic empirical pavement design software. It is found that, on one hand, widening the slab from 13 ft. (4.0 m) to 15 ft. (4.6 m) reduced the transverse cracking from 40.9 to 6.7 ft/mi (7.7–1.3 m/km); but on the other hand, widened slab increased the longitudinal cracking from 174 to 520 ft/mi (33–98 m/km). Similarly, tied concrete shoulder reduced the transverse cracking from 40.9 (curb) to 6.8 ft/mi (7.7–1.3 m/km) but increased the longitudinal cracking from 174 (curb) to 825 ft/mi (33–156 m/km). The same finding can be observed in Fig. 5b and d in terms of cracked slabs in percentage.*

*"The above discussion on the causes for longitudinal cracking on JPCP pavements has led to two possible explanations. First, widened lane and tied concrete shoulder changed the slab geometry (i.e. the length/width ratio), and hence changed the stress/strain distribution in the slab.*

*As shown by Hiller and Roesler [9], the critical fatigue damage location under a widened slab could be changed from the middle along the longitudinal edge to the bottom of the slab at the outside wheel path along transverse joint, which may lead to a longitudinal crack. Second, since the performance of rigid pavement greatly relies on the uniformity rather than the strength of the support, wider slab may magnify the detrimental impact from uneven support. Such magnification may manifest as the development of longitudinal cracking in a widened JPCP pavement." Widened slab and tied concrete shoulder greatly increase the potential of longitudinal cracking.* ***Fig. 6a shows that the number of cases with longitudinal cracking potential increased from 25 to 47 after widening the slab from 12 ft (3.7 m) to 15 ft (4.6 m). This implies that increasing slab width would reduce the length/width ratio and thus change the critical stress location in the slab that would result in more longitudinal cracking.*** *The significance of slab geometry to slab cracking has been widely accepted [19]. Hiller and Roesler [9] found that, when slabs are widened, the critical damage location moves from the longitudinal edge to the transverse edge, which leads to potential longitudinal or corner cracking. Concrete shoulders which are usually tied to the traffic lane further change the length/width ratio, resulting critical tensile stress at the right wheel path and 55 cases with the likelihood of longitudinal cracking."*

Based upon the information supplied in these research papers and the Pavement ME Design Manual of Practice we do not recommend that widening of the concrete slab in Pavement ME be used as a method of decreasing the required thickness of the concrete slab.

***VE Proposal 5-Minimum Vertical Clearances at the Bridges:***

Site specific analysis will need to be conducted prior to analysis of bid savings. Only bridge G-23-AM Westbound was analyzed in the Consultant proposal which would not allow for an increase in elevation so it is infeasible to currently apply this savings to the project. CDOT will re-analyze Bridges G-23-AD, G-23-AF, and G-23-AG for reductions in scope based off of the newly discovered ability to raise the roadway profile.

***VE Proposal 6- Use of High Strength Concrete:***

CDOT will explore further on if 750 psi Flexural strength acceptance of PCCP is feasible. The currently provided Consultant proposal design is not site specific and only general in nature and does not adequately reflect the potential risks or savings to the project. CDOT will analyze site specific designs for the viability of this proposal. Currently the Mechanistic Empirical Pavement Design Guide Manual of Practice also states the following concern which requires further evaluation *"By increasing the PCC strength, the modulus of elasticity also increases, thereby reducing its effect. The increase in modulus of elasticity will actually increase the critical bending stresses in the slab."* The VE design does not modify the modulus of elasticity (which can only be provided from a fully tested concrete mix) and only modifies the Flexural Strength which does not adequately reflect the performance of the mix. CDOT will further evaluate the feasibility of any

savings associated with this change. A change to the Flexural Strength will also require substantial specification and Field Materials Manual coordination and amendment as, mix designs, incentive/disincentives for strength, and other specifications would be impacted.
Discussing with Staff Materials Concrete Group, specifically the PE responsible for reviewing concrete mix designs he stated that it currently appears that contractors are already having trouble meeting the 700 psi mix design requirement in the specifications which then requires they achieve 650 psi in the field. He anticipates that based upon current mix design practices 750 psi requirement may be very difficult for contractors to achieve without introducing substantial brittleness into the concrete mix, utilizing current mix design practices.

***VE Proposal 7- Use Millings Generated on Project for Subbase Material:***
We have evaluated the feasibility of use of RAP millings in the subbase. After consideration that subbase exposure may be potentially less in the base design if VE 5- Minimum Vertical Clearances at the Bridges is re-analyzed, any potential cost savings could be minimal at a greater risk to pavement performance. Also, the following excerpt addresses the suitability of RAP millings as subbase and the risks associated with it;

According to *Laboratory Evaluation on Resilient Modulus and Rate Dependencies of RAP used as Unbound Base Materials* by Qiao Dong PHD and Baoshan Huang PDH from ASCE in February 2014 Issue of *Journal of Materials in Civil Engineering ASCE*. Creep of the RAP millings was a significant issue at 25 degrees Celsius (77 degrees F). *"Exhibited significant permanent deformation and creep behavior at ambient or higher temperature. Thus, the unbound RAP base could contribute significantly to rutting in asphalt pavement."* This same deformation under the concrete slabs could yield non-uniform support of the concrete slabs over time and under loading. This non-uniformity can generate significant cracking in concrete slabs. At this time, it is our recommendation to not proceed with utilization of RAP as a subbase material for a minimal cost savings at increased performance risk to the project.

***VE Proposal 8- Reuse Unsuitable Material for Shouldering***
With modifications to VE Proposal 5 Minimum Vertical Clearances at Bridges, it is expected that only a minimal amount of unsuitable material will be generated for this project. Placement of unsuitable material on shoulders is not recommended due to errant vehicle concerns, however, the ultimate decision of use is to be determined by the Resident Engineer.

***VE Proposal 9- Reduce Concrete thickness by using shorter panels***
Site specific design utilizing this design methodology of decreasing to 12' Length panels allowed thickness to decrease to 9" of PCCP only. However, this does not allow for future diamond grinding thickness which would add ¼" if desired, and as thicknesses are not installed in ¼" intervals but only ½" intervals the concrete thickness would still be most desirably installed at 9.5". To determine if this proposal was advisable, an analysis of additional initial and future costs was conducted to determine if a change to shorter panel widths was to be adopted. Based upon the below analysis it is not recommended to utilize 12' long concrete slabs as a method to reduce the required pavement thickness.

*Also, performing site specific cost analysis;*
*For Initial Cost of construction:*
For both lanes of traffic and assuming no differences in costs at reconstruction areas as these are still being re-designed;

For 9.5" of PCCP at $48.00/SY. for 514,604 SY of non-reconstruct pavement, the original design's pavement is valued at $24,700,992

For the cost of the revised 9" of PCCP design (with an extrapolated cost from the $48.00/SY, since there is not any good bid data currently) at $45.47/SY, the PCCP is valued at $23,399,043 Potential cost savings between these two thicknesses is $1,301,949 in thickness savings.
Reviewing dowel bar costs from suppliers online, for 1.25" diameter dowel bars these materials ranged in costs from $2.50 to $ 5.00 for an epoxy coated 18" long bar. The cost per dowel received from ACPA for the required quantity and to CDOT specification was stated as $ 5.00 per dowel bar. Cost analysis will use $5.00 per dowel bar as this was received from Industry.
Per M 412 of CDOT M and S Standards 2019, the shoulders should be doweled. For this project's inside shoulder there would be 3 dowels, for the outside shoulder there would be 10 dowels, for each lane there would be 10 dowels at two lanes total. This equates to 33 dowels per additional joint.

At 12' length panels, there are 88 more joints per mile, per direction (1,989 total additional joints per project), and at 11.3 miles and 2 directions this yields 65,637 more dowel bars for the project. 65,637 bars at $5.00/bar = $328,185

Changing to 12' lengths of panels yields an additional LF 77,190 LF of joint on the total project according to CDOT OTIS geometry for this project.

Using the Consultant's cost of $ 2.75/LF for 77,190 LF of additional joint sawing and sealing this equals an additional $212,273 of cost. ACPA commented that additional sawing and sealing should have a considered cost of $ 2.50/LF. As this information came from industry, we will utilize $ 2.50/LF for this analysis. The anticipated additional cost at $2.50/LF is $192,975 for the initial construction.

*For Future Rehabilitation Cost;*
For the future rehabilitation treatment of this roadway, it was found that 2018 bid prices for CDOT ranged between 2.10/LF to $4.00/LF for resealing of joints. ACPA provided industry input that $ 2.50/LF is a reasonable expectation of cost. The cost of $ 2.50/LF will be utilized as the basis for cost comparison in this instance. There is an additional 77,190 LF of joint to now re-seal in the future treatment at today's current cost of $ 2.50/LF from ACPA. This is an additional $ 192,975 to CDOT in the future rehabilitation.

Looking at Future Diamond Grinding costs, Pavement ME still predicts that you will need to perform a smoothness rehabilitation between Design Years 27 to 29 at 9" thick pavement regardless of lesser warping and curling predictions. There are now roughly 1,989 more joints across the project limits. As contractors grinding costs are based upon grinding individual slab edges to the specified smoothness tolerances, an additional square yardage of grinding was calculated on these additional slab edges. Assuming wheel widths of trucks being 11" wide with 2" separation between dual tires, and with 4 tires per axle, each wheel path additional grinding would roughly be .44 SY per wheel path, per joint this is now 1.78 SY per joint additional grinding. At 1,989 more joints this is an additional grinding of 3,540 SY. An additional 3,540 SY of grinding at $6.00/SY from Staff Contracts and Market Analysis is an additional $ 21,240 for the additional joints, at a minimum.

Additional Traffic Control costs were also analyzed regarding these additional joints to be ground. At grinding of 50% of the current area at a diamond grind rate of 1/2 lane mile per day, this equates to them grinding 176 slab edges per day. Decreasing the joint length to 12' you will increase the number of slab edges to be 220 in a ½ mile that needs to be ground. This is an additional 44 slab edges per ½ mile. As you have 1,989 more joints total on the project, splitting this into slab edges to grind you would have an additional 3,978 edges to grind across the job in the through lanes.

Assuming the 176 slab edges is what their production per day would be this would equate to an increase of 23 working days to complete this additional work. Utilizing the costs generated from the Traffic Control costs for the LCCA at $ 2,831/day for Traffic Control, this is an additional $ 65,113. Additional cost related to User Cost is neglected from the table below as it is a soft cost. Pro-rating the User Cost from the LCCA to $2,431/day, the additional User Cost value is $55,913. Maint. Costs per the Pavement Design Manual when used in the LCCA generation was $640 per Lane Mile per Year. Assuming most of the Maint. cost is related to joint maintenance and slab repair, there is an increase of 25% of panels in the through lanes. Assuming a linear relationship in cost, 25% of $640 is $160 per lane mile per year. There is 46.335 lane miles on this project according to OTIS. Applying this additional cost to the lane miles this is an increase of $ 7,413 per year in Maint. Costs for the project limits. Assuming a 40 Year Design Life for this pavement according to the LCCA requirements, this equates to an additional $296,520 over time.

Current research indicates that there are potential issues related to Length/Width ratios when tying concrete to shoulders. When tying to the concrete shoulder, you have effectively changed the Length to Width aspect ratio of the concrete slab so that the slab is now functioning as longer in Width than Length. This potentially increases the risk of longitudinal cracking, which cannot be analyzed by the Pavement ME software. If you Run the Pavement ME software with the shoulder untied at the 9” PCCP thickness the pavement fails its design threshold criteria by Year 26 which is below CDOT Pavement Design Manual requirements. As there is not currently a good indicator of potential longitudinal cracking, we analyzed the remaining difference in savings between the proposed shortening of slab option and the longer slab option to determine what additional amount of slab replacement would be needed to offset any potential savings with the shortening of panel length. Utilizing 2018 bid costs, it was determined that slab replacement in the prescribed range of thickness is roughly $114.37/SY for the cost of the new pavement and $ 13.84/SY for existing concrete removal prior to patching. This makes the removal and replacement cost roughly $128.21/SY. Considering that a 12’ by 12’ slab is roughly 16 SY, this make a single slab replacement an effective cost of $ 2,051.36/slab. Considering the current savings is $ -204,941 (as shown in the table below) this would allow for replacement of 100 slabs roughly in the project limits before the savings is fully offset. Considering that there are roughly 19,890 panels in the through lanes for this project, at the 12’ by 12’ panel size, if the longitudinal cracking of slabs percentage increased by 0.51% any savings on the project would be lost by utilizing the 12’ by 12’ panels.

Previously cited papers *(Longitudinal Cracking of Jointed Plain Concrete Pavements in Louisiana: Field Investigation and Numerical Simulation* by Danny Xiao and Zhong Wu, and IHRB Project TR-700 *Prevention of Longitudinal Cracking in Iowa Widened Concrete Pavement)* further elaborate on the length to width changes of slabs with tied shoulders and lesser performance regarding longitudinal cracking.

A few other items to consider are that per FHWA’s paper from January 2019 titled Technical Advisory Concrete Pavement Joints, T5040.30, one thing they say to consider before shortening transverse joint spacing is, *“More closely spaced joints can also adversely affect ride quality and tire/pavement noise.”* Not in FHWAs Advisory but to also consider is that an increase in number of joints, increases the capability of water to infiltrate the pavement into both the PCCP layer and the underlying HMA layer in this case. There is potential this may cause additional degradation over time.

Considering the below cost breakdown and its minimal savings and the increased risk of potential longitudinal cracking and potential variability in costs of each individual item, we do not recommend utilizing the 12’ length of concrete panels as a method to decrease the slab thickness.

Also, this region does not have any performance data available on the long term performance of 12' long slabs to verify additional costs or performance. Considering that the pavement does not meet Pavement ME design criteria utilizing an untied shoulder (which would represent the ideal length to width ratio of the slab) we do not currently believe that this is a viable alternative at this time for CDOT.

| | | |
|---|---|---|
| Cost of 9.5" PCCP @ $ 48/SY | $24,700,992 | |
| Cost of 9" PCCP @ $ 45.47/SY | $23,399,043 | |
| Cost Savings to Switch to 9" of PCCP | -$1,301,949 | |
| Cost of Additional Dowel Bars | $328,185 | |
| Cost of Additional Joint Sealing | $192,975 | |
| Cost of Additional Future Joint Re-Sealing | $192,975 | |
| Cost of Additional Future Diamond Grinding | $21,240 | |
| Cost of Additional Future Traffic Control | $65,113 | |
| Increased Maint. Cost over Life of Roadway | $296,520 | |
| Soft Cost of Additional User Cost for Future Treatment | $55,913 | (Not added into cost below) |
| | ***-$204,941*** | Savings to use 9" PCCP |
| | | |
| Additional Number of Longitudinally Cracked Panels to Nullify Savings | 100, 12' x 12' Panels | |
| Percent Increase in Longitudinal Cracked Panels to Nullify Savings | 0.51% | |

One final note to consider on all of the above represented costs, is that any additional CE costs are neglected for simplicity of the analysis.

*Notes on Inaccuracies of Consultant's Assumptions*
Consultant analysis says that 11" of PCCP cost $65.00 per SY and says it is from preliminary cost analysis. This is incorrect as preliminary analysis and cost data received from Contract and Market Analysis provided a price of $ 60/SY.

The Consultants analysis of the additional dowel bar count is incorrect as the consultant assumed only 20 additional dowels per joint. M Standard 412 says shoulder shall be doweled at 12" O.C. in the shoulders. This contrasts the consultants count of 20 bars per additional joint versus the actual 33 per joint that would be required. Considering this is an Interstate, doweled shoulders is preferred per our standards.

There is a significant discrepancy between anticipated costs from the Consultant at $ 1.00 per dowel versus our research which yielded costs between $2.50 - $ 5.00 per bar. ACPA reviewed the total count of potential dowel bars to CDOT standards and commented that the anticipated price for dowel bars at this quantity should be assumed to be $5.00 per dowel bar.

The Consultant's analysis neglected Future Rehabilitation and Traffic Control costs and increased Maint. Costs over time.