# PENA BOULEVARD

A successful Project with true sustainability and cooperation between the owner and contractor

# Pena Condition

- Pena Boulevard is the main roadway to the very busy Denver international Airport. The road is a four lane divided highway which traffic cannot be interfered with in any way. Pena Boulevard from 2nd Creek to 64th Avenue was a concrete road which had a very severe Alkali-Silica Reactivity (ASR) problem. The road was requiring a lot of maintenance and needed to be replaced. The road was originally built in the early 90's

# Project Specifics

- Project is approximately 2 miles long and constructed in 3 phases from 2012 to 2014.
- Pena is a divided highway with 2 lanes in each direction . Pavement is 40′ wide in each direction with 4 bridges.
- The project was 100,000 SY of 11″ Dowelled concrete pavement placed on crushed existing concrete left in place and two inches of recycled concrete base.  Easily a 50 year design
- To provide smooth transitions at the bridges and the ends of the projects, complete reconstruction was completed for 500 feet

# Overhead look at Downtown Denver

# Complete Phase 1 and 2

# Overhead of entire project

# Recycled concrete base

# Traffic maintenance

- In order to maintain two lanes of traffic in both directions two very unique features were used.

1. A two lane asphalt road was built between inbound and outbound Pena. This road was used to build each side and was maintained for two years
2. A detour was built around phase 3 with a temporary bridge which has been removed.

# Temporary Bridge

# Paving Operations

Castle Rock construction is committed providing quality concrete paving which is smooth.

In 2011 Colorado changed the specification for smoothness from a Profile Index to an International roughness index specification. DIA use a Mean Roughness Index.

The PI was easier to obtain incentives but a good PI specification does not necessarily relate to a good IRI.

CRCC was committed to meeting this change.

The industry had IRI's in the high 80s at the beginning and now as low as the 50s and 60s.

# CRCC Strategy to Improve Ride Quality

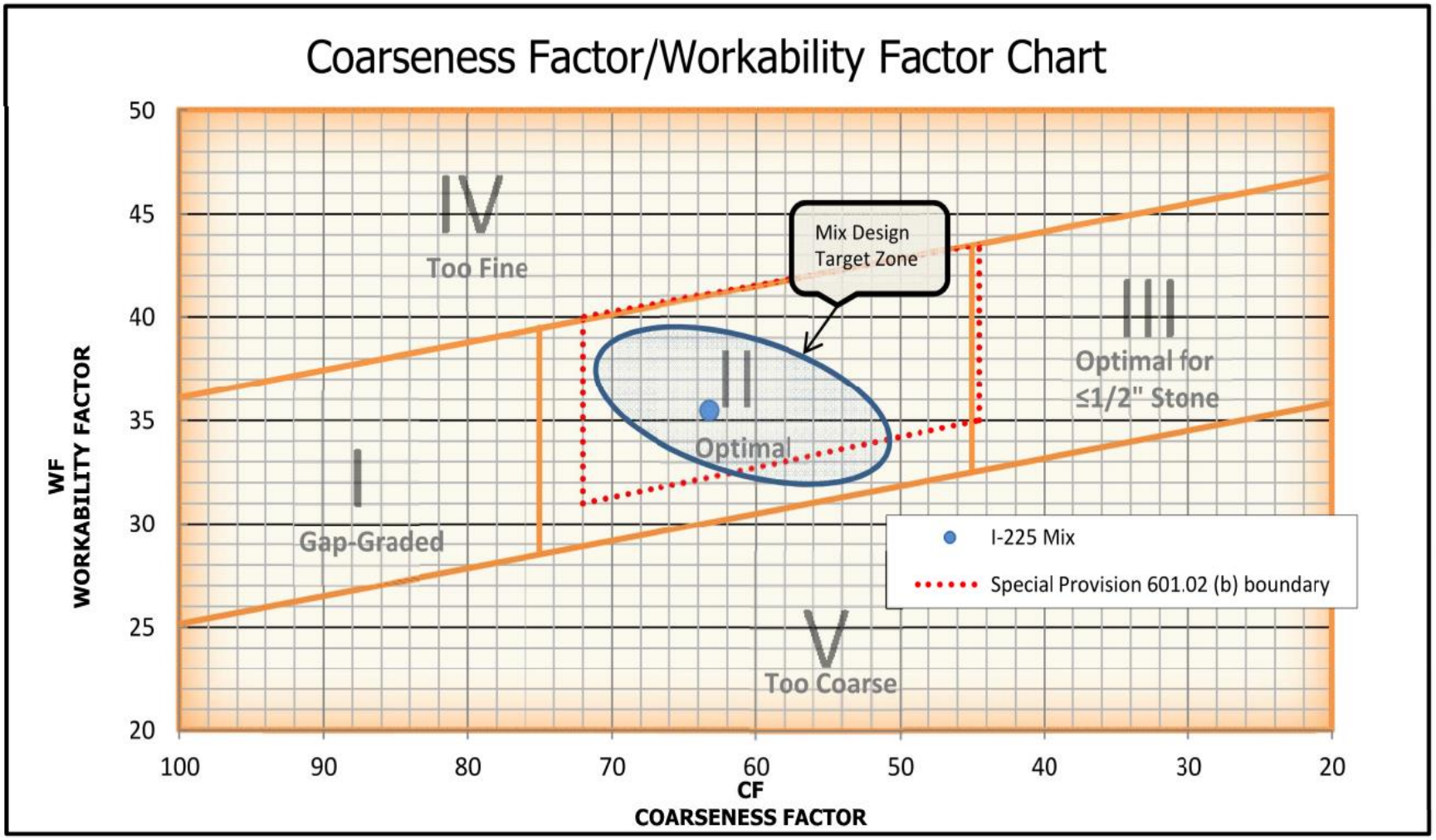
- Optimized Mix designs
- Modifications at the batch plant
- Changes in the fine grade operation
- Paver Set up
- Paving Operation

# Optimized Mix Design Specification

- A modified Shilstone box was established
- CRCC would pre-blend aggregate prior to feeding into batch plant
- The aggregate blend is weighed as a Combined Aggregate
- Tests on gradation were done every 3 hours to insure the agency that the mix was in compliance with the mix design
- DIA was very much in favor of this new optimized specification and now it is a standard specification and is the choice of the contractor

# Step 1: Mix Design

- All of our mix designs are engineered with 4 aggregates - #4 Course (1 ½”), #67 Course (3/4”), #9 aggregate (squeegee) and Concrete Sand
- Engineering uses 45 power curve, the hay stack curve, Mix Optimization data and coarseness and workability factor charts are used to obtain a well graded aggregate blend.
- Total cementitious is minimum 530 Lbs.
- CRCC has successfully been using 422 Lbs. cement and 108 Lbs. of Type F flyash.
- Mix Design requires 700 psi flexural strength in lab aiming at a 650 psi design strength

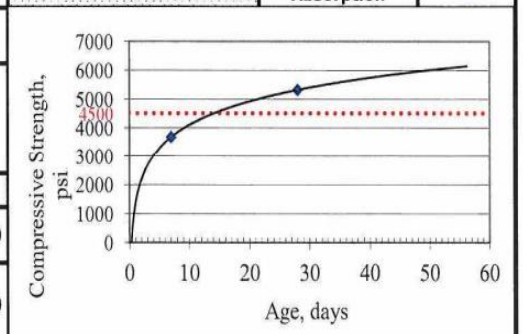

Coarseness Factor/Workability Factor Chart
IV
Too Fine
Mix Design
Target Zone
III
Optimal for
≤1/2" Stone
II
Optimal
I
Gap-Graded
V
Too Coarse
I-225 Mix
Special Provision 601.02 (b) boundary
WF
WORKABILITY FACTOR
50
45
40
35
30
25
20
100
90
80
70
60
50
40
30
20
CF
COARSENESS FACTOR

# Concrete Mix Design - Compressive Strength Criteria

| | | | |
|---|---|---|---|
| Project Number: | D12.047, Castle Rock Construction Company | Report Date: | 29-Jul-12 |
| Project Name: | I-225 PCCP Mix Designs | Technician: | KMC/CCR |
| Lab ID Number: | 124150 | Reviewer: | K. Clark |
| Description: | CDOT Class P - Modified (5.6 Sack Mix) | | |
| Client: | Castle Rock Construction Company | | |
| Concrete Mix Design by: | Cesare | Date Performed: | 12-Jun-12 |
| Client Mix Design ID: | NA | Lab Batch Size, $ft^3$: | 7.5 |

| Design | | | | | Physical Properties | |
|---|---|---|---|---|---|---|
| Material | Source and Type | Specific Gravity | Batch Weights ($yd^3$) | | *As Tested by Cesare* | |
| Cement (ASTM C 150) | Holcim Envirocore GU (80%) | 3.15 | 422 | lb | Slump, in. | 2.00 |
| Fly Ash (ASTM C 618) | Headwaters - Bridger Class F (20%) | 2.40 | 108 | lb | Air Content, % | 7.0 |
| *Coarse Aggregate #1 (ASTM C 33) | Aggregate Industries - Morrison Pit - ASTM Size #4 | 2.69 | 440 | lb | Temperature, °F | 73 |
| *Coarse Aggregate #2 (ASTM C 33) | Aggregate Industries - Thornton Pit - ASTM Size #67 | 2.61 | 1036 | lb | Unit Weight, pcf | 142.5 |
| *Intermediate Aggregate (ASTM C 33) | Aggregate Industries - Thornton Pit - ASTM Size #9 Squeegee | 2.59 | 691 | lb | Yield, CF/CY | 27.2 |
| *Fine Aggregate (ASTM C 33) | Aggregate Industries - Thornton Pit - Washed Concrete Sand | 2.62 | 973 | lb | Relative Yield | 1.01 |
| Water | Municipal | 1.00 | 209 | lb | w/(c+p) Ratio | 0.39 |
| Air Entraining Agent (ASTM C 260) | Euclid - Eucon AE92 (0.7 oz/cwt) | n/a | 3.5 | oz | **Aggregate Absorptions, %** | |
| Water Reducer-Normal (ASTM (C494) | Euclid - Eucon LW (5.7 oz.cwt) | n/a | 30.0 | oz | Fine Aggregate: | 0.9 |
| Target Air Content, % | 6.0 | -- | -- | | Coarse Agg. #1 | 0.7 |
| *Aggregate mass determined at SSD condition | | **Total:** | **3879** | lb | Coarse Agg. #2 | 0.9 |
| | | | | | Interm. Agg. | 0.9 |
| | | | | | **Combined Absorption** | **0.87** |

| Flexural Strength Data | | | |
|---|---|---|---|
| Date | Test Age, days | Strength, psi | Ave., psi |
| 06/19/12 | 7 | 605<br>600 | **605** |
| 07/10/12 | 28 | 710<br>715<br>695<br>- | **705** |
| **Compressive Strength Data** | | | |
| 06/19/12 | 7 | 3870<br>3490 | **3680** |
| 07/10/12 | 28 | 5020<br>5480<br>5460 | **5320** |



CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

# CONCRETE MIX OPTIMIZATION CHARTS

Project Number: D12.047, CRCC - I-225 Mix Designs
Project Name: I-225 Mix Designs
Lab ID Number: 124079
Sample Location: A. I., Morrison and Thornton Pit
Description: CDOT Class P - Optimized Mix (4200 psi compressive @ 28 days and 700 psi Flexural @ 28 days)

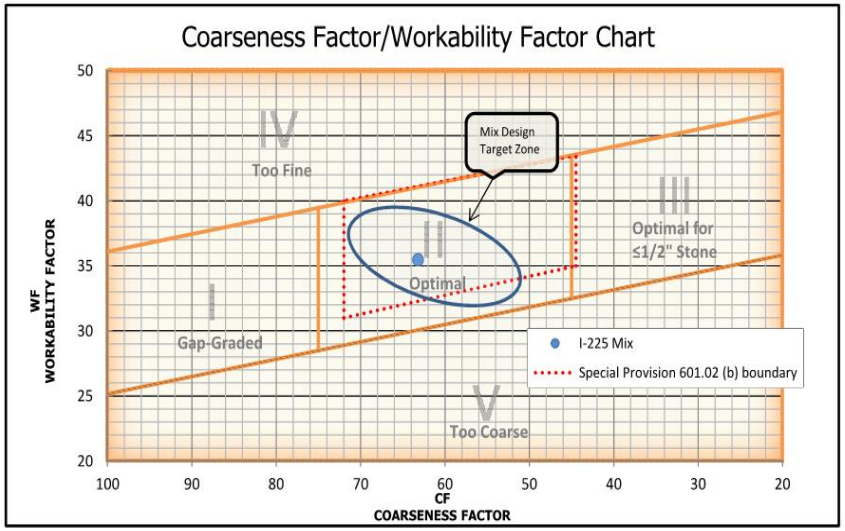
Date: 10-Apr-12
Technician: KMC/TWT
Reviewer: K. Clark

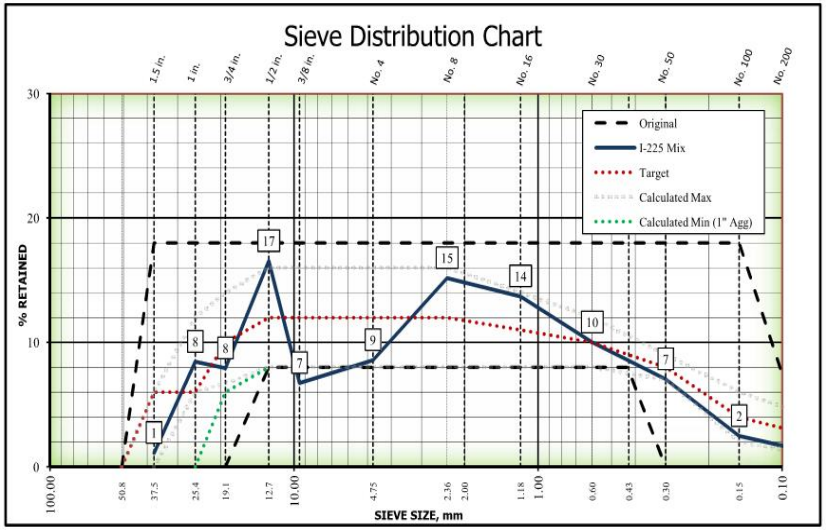
| Material: | Cement | Fly Ash | Aggregates | Admixtures | Water, lb |
|---|---|---|---|---|---|
| Source & Type: | Holcim Envirocore, Portland | Bridger Class F, Headwaters | A. I., Morrison and Thornton Pit | Euclid AE92<br>Euclid LW | Municipal |
| Quantitiy: | 422 lbs | 108 lbs | 3140 lbs | 3.5 oz. AE<br>23 oz. WRA | 207 |

## MIX OPTIMIZATION DATA

| Material Type: | | Morrison #4 | Thornton #67 | Thornton #9 | Thornton WCS | Target | I-225 Mix |
|---|---|---|---|---|---|---|---|
| Percent of Combined Blend: | | 14.0% | 33.0% | 22.0% | 31.0% | | |
| | | | | | 100.0% | | FM Total 4.73 |
| Sieve Size | Sieve Size to 0.45 | % Passing | % Passing | % Passing | % Passing | | |
| 1.5" | 5.145 | 92 | 100 | 100 | 100 | 99 | 99 |
| 1" | 4.287 | 34 | 99 | 100 | 100 | 91 | 90 |
| 3/4" | 3.771 | 8 | 86 | 100 | 100 | 82 | 83 |
| 1/2" | 3.138 | 3 | 38 | 100 | 100 | 70 | 66 |
| 3/8" | 2.754 | 2 | 18 | 100 | 100 | 60 | 59 |
| #4 | 2.016 | 2 | 2 | 85 | 100 | 47 | 51 |
| #8 | 1.472 | 2 | 1 | 26 | 94 | 34 | 35 |
| #16 | 1.077 | 2 | 1 | 6 | 64 | 22 | 22 |
| #30 | 0.795 | 1 | 1 | 2 | 35 | 12 | 12 |
| #50 | 0.582 | 1 | 1 | 1 | 13 | 5 | 5 |
| #100 | 0.426 | 1 | 1 | 1 | 5 | 2 | 2 |
| #200 | 0.312 | 0.8 | 0.5 | 0.5 | 2.3 | 0.0 | 1.1 |

| | | | | | |
|---|---|---|---|---|---|
| W/(C+P) ratio: | 0.39 | Workability Factor: | 35.5 | Fineness Modulus (WCS): | 2.89 |
| | | Coarseness Factor: | 63.2 | Mortar Fraction: | 48.2% |
| Theo. UW, pcf: | 143.6 | | | Paste Fraction: | 22.9% |
| | | | | Aggregate Fraction: | 71.1% |

# Step 2: Modifications to the Plant

- Four Bin Feeder for the aggregate
- Pug Mill to pre-blend the aggregate
- Aggregate sent to plant as a single aggregate Job Mix Formula
- Aggregate gradation tested every 3 hours at the pugmill to insure gradation matches Mix design
- Aggregate moisture determined for the mix

# Plant Modifications Four Bin Feeder

# Plant Modifications

# Plant Modifications

# Plant Modifications

# Plant Modifications

# Other Things which are monitored at plant

- Drum in good shape
- Monitor aggregates as they come in to insure gradation is same as mix design
- Proper stock pile management. Pay close attention to where new aggregate is dumped and how loaders feed out of piles.
- Maintain consistent concrete slump of 1 ¼" to 1 ¾" and monitor constantly at paver
- No water/cement ratio over .42 (generally .39 to .40 in paving)

# Step Three: Changes to Fine Grade operation

- Wire used instead of string line – CRCC not quite ready for wireless.
- Winches used on the wire every 500 feet.
- Width between wire lines no more than 1 inch (paving width plus offsets)
- Pad line is profiled by QC before trimming and deficiencies are fixed before trimming.
- String line tautness is checked every morning with a 3 lb. weight – if deflection is more than .02" the wire line must be tightened.

# Step Four: Paver Set up

- All of our mainline pavers are Dowel Bar Inserted (DBI) machines.
- Good paver setup which includes:
  - Paver straight, tight and flat. Checklist used.
  - Sensors parallel and across from each other and set to slope of the paver pan
  - Vibrator monitoring system working
  - Baffles in the mud box to control flow of concrete in box.
  - Vibrator nose split at nose of the pan
- Spreader set up to fit just inside of paver tracks

# Step 5: Paving Operation

- A good dump plan/dump man
- Spreader just barely in front of paver to consistent concrete flow to paver
- Keep trucks and loader from compacting concrete in dump process
- Control head pressure at paver with spreader. Keep head at strike off on paver at the middle of strike off
- Control the head in grout box to the top of the vibrator bar
- Vibrator monitoring system
  - 4500 VPM when on thin or hard bases
  - Higher as thicker
  - Consistent across the paver
- Control of the roll at the oscillating beam. Need volley ball size or smaller – control with minor turns <1/2 turn on front sensors

# Step 5: Paving Operations

- Constant speed of paver - stop as little as possible but stop instead of slowing down
- Hourly testing of slump and air of the concrete
- Don't walk on slab at DBI unless absolutely necessary
- Manage speed of OCB – as slow as possible and relative to the speed of the paver.
- Real Time Profiler (RTP) is used to manage cause and effects of adjustments – NOTES must be taken to facilitate analysis.
- V Float used to eliminate chatter – must be checked for straightness and straightened as necessary
- Do not put finishing tools (bull floats/Avalon) on the slab – finish only the edge and a finisher on the bridge patrolling for holes and patching with margin trowel
- Make tining as light as possible to meet specification keeping the curing and tining machine a constant distance behind paver
- Extra care taken with headers

# Paving Operations- Dump Plan

# Paving Operation- Spreader

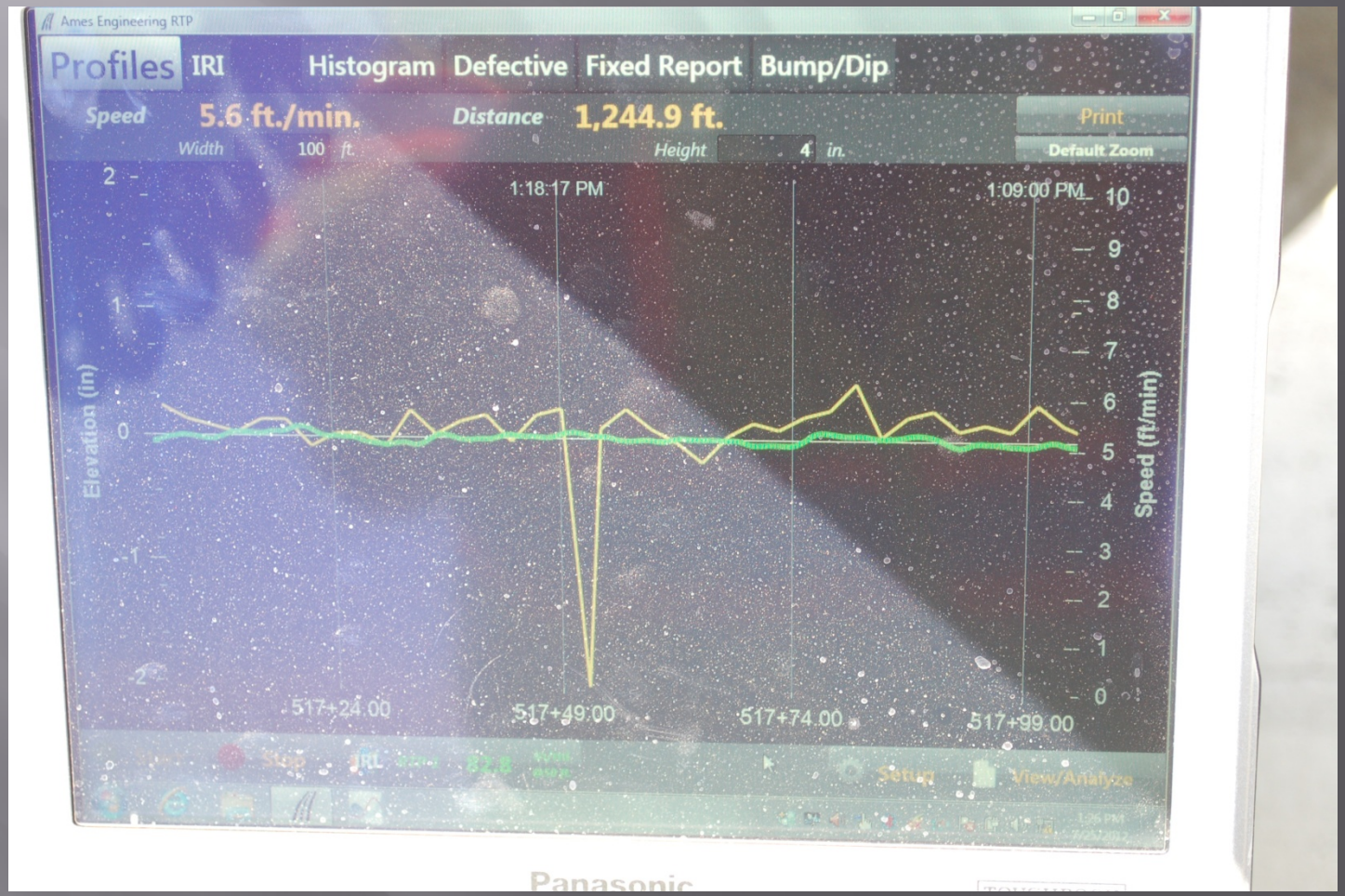
# Paving Operations- Spreader close to Paver

# Paving Operations

# Paving Operations- Control Roll Size

# Paving Operations- RTP

# Paving Operations- RTP



# Paving Operations- V Float

# Conclusions

- Mix design – an optimized mix design with aggregate producer providing a very consistent aggregate
- Proper stockpile management
- Mixing the aggregate before introducing into concrete drum (a more consistent mix)
- Monitoring air and slump at the paver hourly – consistent concrete
- Use of a spreader to take all of the pressure off the paver
- Tautness and width of string line and good pad line
- Maintain consistent level of concrete in front of paver and grout box

# Conclusions

- Buy in & commitment
- Consistent level of vibration across the paver – lower on hard bases or overlays
- Oscillating beam as slow as possible and in line with speed of paver
- Consistent speed of paver
- Control size of roll in front of OCB
- V Float to help control chatter
- Real time profiler to monitor effects of changes and processes
- Keep texture machine at a constant distance behind paver and as light as possible to make specifications

# After Thoughts

- The purpose of this proportioning and mixing was to aid in the production of a more consistent concrete batch and a better platform for the concrete paver with the ultimate goal of producing a smoother ride on the concrete paving. Portland-limestone cement proved to be consistent and helped contribute to the achievement of the quality performance incentives. The 28 day flexural strengths average was 685 PSI. DIA and the Design Team were very happy with the optimized portland-limestone concrete mix design and ride numbers. All steel was checked with MIT Scan to insure proper placement.
- The City and County of Denver and CRCC are very proud of this project and the results. The project is aesthetically pleasing, sustainable and was built with as little inconvenience as possible to the surrounding area and flying public.

# Contact Information

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