Agenda

- Mix Designs
- Pavement Design
  - Full Depth
  - Thin Bonded Overlays
- Steel In Pavement
- Finishing and Curing
- Common Issues
- CDOT Recent Specification Changes
<table>
<thead>
<tr>
<th>Concrete Class</th>
<th>Required Field Compressive Strength (psi)</th>
<th>Cementitious Content: Minimum or Range (lbs/yd³)</th>
<th>Air Content: (Total)</th>
<th>Water Cementitious Ratio: Maximum or Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>4500 at 28 days</td>
<td>N/A</td>
<td>5 - 8</td>
<td>0.45</td>
</tr>
<tr>
<td>BZ</td>
<td>4000 at 28 days</td>
<td>610</td>
<td>N/A</td>
<td>0.45</td>
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<tr>
<td>D</td>
<td>4500 at 28 days</td>
<td>615 to 660</td>
<td>5 – 8</td>
<td>0.45</td>
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<tr>
<td>DT</td>
<td>4500 at 28 days</td>
<td>700</td>
<td>5 – 8</td>
<td>0.44</td>
</tr>
<tr>
<td>E</td>
<td>4500 at 28 days</td>
<td>520</td>
<td>4 – 8</td>
<td>0.44</td>
</tr>
<tr>
<td>H</td>
<td>4500 at 56 days</td>
<td>500 to 640</td>
<td>5 – 8</td>
<td>0.42 - 0.44</td>
</tr>
<tr>
<td>HT</td>
<td>4500 at 56 days</td>
<td>500 to 640</td>
<td>5 – 8</td>
<td>0.42 - 0.44</td>
</tr>
<tr>
<td>P</td>
<td>4500 at 28 days</td>
<td>520</td>
<td>4 – 8</td>
<td>0.44</td>
</tr>
<tr>
<td>S35</td>
<td>5000 at 28 days</td>
<td>615 to 720</td>
<td>5 – 8</td>
<td>0.42</td>
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<tr>
<td>S40</td>
<td>5800 at 28 days</td>
<td>615 to 760</td>
<td>5 – 8</td>
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<tr>
<td>S50</td>
<td>7250 at 28 days</td>
<td>615 to 800</td>
<td>5 – 8</td>
<td>0.38</td>
</tr>
</tbody>
</table>
What is in a mix design?

Aggregates:
- Fine
- Coarse

Cement
- Portland
- Fly ash and other pozzolans

Admixtures
- Air Entrainers
- Water Reducers
- Accelerators
- Retarders

Water
Mix Design

Why Do We Care?

Different material delivery has happened. Make sure your material sources match the mix design.

Aggregates:
  - Strength
  - Workability
  - Reactivity
  - Polishing

Cement:
  - Setting Time
  - Sulfate Resistance
  - “Green” Initiative
  - Heat
Mix Design

Why do we care?

Pozzolans:
  F and C
  ASR
  Fresh Properties
  Sulfate Resistance
  Permeability

Admixtures:
  Workability
  Hardened Properties

Water:
  Less is more....to a point
Aggregate Gradations for Pavement

Optimized Gradation
- Called Shilstone or KU mix

\[ CF = \left( \frac{S}{T} \right) \times 100 \]
- Where:
  - \( S \) = Percent Cumulative Retained on 9.5 mm (3/8 inch) Sieve
  - \( T \) = Percent Cumulative retained on 2.36 mm (No. 8) Sieve

WF is the percent passing the 2.36 mm (No. 8) sieve
Importance of Testing

- Slump
- Air
- Yield
Mixing

Concrete can be mixed in various ways;

Concrete must be placed within 90 minutes if it is delivered in an agitating truck

- Placement time may be extended if certain criteria are met.

and within 60 minutes if it is delivered in non-agitating trucks
Air Content Adjustment

The contractor (at his discretion) may add an air entraining admixture at the job site to conform to the specifications.

The air entrain admixture must be re-mixed a minimum of 20 revolutions.

The contractor may adjust the air content multiple times prior to the QA test by CDOT.
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Pavement Design

Why do we care?
Pavement Design

Design is based on assumptions
• Subgrade and Subbase quality
• Pavement thickness
• Material

These are all items that can be controlled on site!
Pavement Design

Conventional Concrete Pavements

Subbase

Subgrade
Start With Subgrade Uniformity

Uniformity is more important than strength

Proof roll!-18 kips per axle
Concrete

Ensure the correct concrete is delivered to site

Check Batch Tickets!
Whitetopping - 412.10

- AKA Thin Bonded Concrete Overlays of Asphalt
- CDOT has done over 1 million square yards of whitetopping
- We will probably not go less than 4 inches over asphalt pavements
- It is possible to go as low as 2 inches
- CDOT recommends a minimum of 5 inches
M-Standard D-412-2
Whitetopping- 412.10

Surface Preparation

• Moisture coat
  • Light mist of water
  • No excessive ponding
  • The concrete shall be placed while the surface is still wet
• Concrete will not be placed when the surface temperature of the HMA is 120 degrees Fahrenheit or greater
Whitetopping- 412.10
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Steel In Pavement

Two Types

- Dowel Bars
- Tie Bars
Load Transfer

Poor Load Transfer

Good Load Transfer
Load Transfer

1.25” dia. for D < 10”
1.5” dia. for D > 10”
Don’t Cut Ties
MIT Scan/Dowel Bar Specification
412.13
MIT Scan Specification – 412.13

- Rotational Alignment
  - Any bar with a misalignment greater than 1.5in.
  - Rotational alignment is the value of the hypotenuse from the horizontal skew and vertical tilt
Joint Score

- Joint Rejection Criteria

  - Any joint with a Joint Score greater than 10. An individual joint may be allowed if the two longitudinally adjacent joints each have a joint score less than or equal to 10

<table>
<thead>
<tr>
<th>Range of Rotational Misalignment</th>
<th>Weight</th>
</tr>
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<tbody>
<tr>
<td>&lt; 0.6 in.</td>
<td>0</td>
</tr>
<tr>
<td>≥ 0.6 in and &lt; 0.8 in.</td>
<td>2</td>
</tr>
<tr>
<td>≥ 0.8 in and &lt; 1 in.</td>
<td>4</td>
</tr>
<tr>
<td>≥ 1 in</td>
<td>5</td>
</tr>
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</table>
Joint Score

- Joint Rejection Criteria
  - Any joint that does not have at least three acceptable dowel bars in each wheel path.

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</table>
MIT Scan Specification – 412.13

• Longitudinal (side) shift
  • Any bar that is not embedded at least 6 inches on each side of the joint
• Depth:
  • Any bar within the top 3 inches of the pavement or at a depth less than the saw-cut depth.
  • Any bar within the bottom 3 inches of the pavement
Corrective Measures

- Rotational misalignment.
  - Saw-cut the misaligned bars. Joints with less than three un-cut bars in each wheel path will require the addition of dowel bars using an approved dowel bar retrofit method.

- Longitudinal (side) Shift and missing bars
  - Addition of dowel bars using an approved dowel bar retrofit method.

- Depth.
  - Inadequate cover above the bar—Remove the bar and install a replacement bar using an approved dowel bar retrofit method.
  - Inadequate cover below the bar—Addition of dowel bars using an approved dowel bar retrofit method.
Tie Bar Spacing

- Tie bar spacing has changed from 30 inches to **36 inches**
  - This eliminates one tie bar per panel
  - Minimized MIT scan interference with dowel bars
  - QA testing is now done with the MIT Scan for tie bars
Tie Bar Design

• All joints are now required to be tied on divided highways
  • CDOT has experienced problems with separations of slabs
  • If that is a problem cross stitching can be used to tie the panels
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Why do we care?
412.12 Finishing

- The sequence of operations shall be strike-off and consolidation, floating, and final surface finish.
- Water shall not be added to the surface of the concrete to assist in finishing operations.
- The surface shall be finished to a uniform texture, true to grade and cross section, and free from porous areas.
- When the finishing machine (either form or slip form) or hand finishing method, leaves a surface that is not acceptable, the operation shall stop and corrective action shall be taken.
- Inability of the finish machine to provide an acceptable surface finish, after corrective action, will require replacement of the finish machine.
Hand Finishing

The Engineer shall be notified prior to hand finishing work and the proposed hand finished work shall be addressed in the Quality Control Plan for concrete finishing.

Hand finished concrete shall be struck off and screeded with a portable screed that is at least 2 feet longer than the maximum width of the slab to be struck off.

It shall be sufficiently rigid to retain its shape.

Concrete shall be thoroughly consolidated by hand vibrators.
Hand Finishing

Hand finishing shall not be allowed after concrete has been in place for more than 30 minutes or when initial set has begun unless otherwise approved by the Engineer.

Floating: The Contractor shall not use floats made of aluminum
Where posted speeds are 40 mph or higher, the surface shall be given a longitudinal metal tine finish immediately following turf drag. Tining is not required where posted speeds are less than 40 mph.

Tining shall produce grooves of 1/8 inch x 1/8 inch spaced 3/4 inch apart and parallel to the longitudinal joint.

Longitudinal tining shall stop at the edge of travel lanes.

Tining devices shall be maintained clean and free from encrusted mortar and debris to ensure uniform groove dimensions.

The tining finish shall not be performed too early whereby the grooves may close up.
Acceptable Tining
Unacceptable Tining
Texturing Specification –
106.06 (a)

- Sand Patch Test
  - Type 1 Beads are Used
  - More Details in CP 77
  - Minimum of 0.05 Inches
412.14 Curing

Immediately after the finishing operations have been completed the entire surface, including tined grooves and exposed sides of the newly placed concrete, shall be sprayed uniformly with an impervious membrane curing compound.

- 1 gal per 120sf once
- Or 1 gal per 150sf twice
- Apply within 30 minutes
Curing – 412.14

- ASTM C309, Type 2
- The compound shall be volatile organic content (VOC) compliant
- Curing is more important for durable surface texture
- White or fugitive cure are preferred
Smoothness 105.07

Measured in HRI (Halfcar Roughness Index)
  • 2 Categories, I and II
Pavement should be profiled within 14 days after completion of the paving operations

Profiler must be from the CDOT certified profiler list (online)

Sequence
  • Paving
    • Initial Profile (Allow for 10 days for results)
  • Grinding
    • Final Profile
Agenda

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Warping and Curling

- CDOT has seen many instances of warping and curling
  - Temperature differential at placement
  - Improper curing

- How do we prevent it?
Scaling

• Usually caused by finishing issues
  • Over finishing
  • Adding water
  • Curing

• How do we prevent it?
ASR

- Is caused by aggregate and cement reactions
- How do we prevent it?
Ettringite

- Looks a lot like D cracking
- At concrete pavement joints
- What causes it?
- How do we prevent it?
Dowel Misalignment

- Most of the time the saw cut is wrong
- Pushing of baskets
- Missing dowel bars

- Can cause:
  - Joint Deterioration
  - Joint Locking
  - Cracking
MIT Examples
Agenda

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Flatwork Finisher (601.12)

No longer a requirement for the ACI Flatwork Finisher Certification on CDOT projects

Changed in February, 2011
Flow Fill (206.02)

Minimum compressive strength of 50 psi at 28 days

Flow-fill shall have a slump of 7 to 10 inches, when tested in accordance with ASTM C143 or a minimum flow consistency of 6 inches when tested in accordance with ASTM D6103.

Removability Modulus, RM, is calculated as follows:

\[
RM = \frac{W^{1.5} \times 104 \times C^{0.5}}{10^6}
\]

Where : 
W = unit weight (pcf)  
C = 28-day compressive strength (psi)

RM must be 1.5 or less

Changed in April, 2012
Grouted Rip Rap (105.07)

### SECTION 507
**SLOPE AND DITCH PAVING**

**507.05 Grouted Riprap Slope and Ditch Paving.** Concrete mortar for grouted riprap slope and ditch paving shall meet the requirements of Section 601 with the following exceptions:

| Field Compressive Strength (28 days) (Not a specification requirement) | 2000 psi |
| Field Compressive Strength (28 days) (Not a specification requirement) | 2000 psi |
| **Minimum** Cement Content | 560 lbs./cu. yd. |
| Air Content | 6-9% |
| Slump, AASHTO Designation T-119 | 5-9 inches |
| Fine Aggregate, AASHTO M-6 | 70% 65-75% |
| Coarse Aggregate, AASHTO M-43 | 30%, 2.36 mm (Nominal maximum size) |
| Polypropylene Fibers (1" fiber length or equivalent) | 1.5 lbs./cu. yd. |
It is more clearly defined that the Contractor shall provide QC for structural concrete.

When the QC and QA air content measurements differ by more than 0.5 percent, both the QC and QA air meters shall be checked in accordance with ASTM C 231.

Changed in May, 2014
Specifications require that concrete is required to be within 2.0 inches of the approved concrete mix design. High slumps will be retested and if the slump is exceeded a second time, that load is rejected. Low slumps can be brought up by adding water or a water reducing admixture.

Changed in July, 2011
Adding 25% extra cement when depositing concrete underwater is no longer allowed.

Concrete deposited under water shall be carefully placed in a compact mass in its final position by means of a concrete pump and tremie. The discharge or bottom end of the tremie shall be lowered to contact the foundation at the start of the concrete placement and shall be raised during the placement at a rate which will insure that the bottom or discharge end of the tremie is continuously embedded or buried in fresh concrete a minimum of 12 inches.

Changed in May, 2013
Fiber Reinforced Concrete (601.03 & 601.05)

Unless otherwise specified, a minimum of 3.5 pounds per cubic yard of polyolefin fiber reinforcement shall be evenly distributed into the mix. ASTM C1116 and ASTM D7508.

Unless otherwise specified, a minimum of 4.0 pounds per cubic yard of macro polyolefin fiber reinforcement shall be evenly distributed into the mix. Macro Fiber-Reinforced Concrete shall have a residual strength of 170 psi as determined by ASTM C1609. Macro polyolefin fibers shall meet the requirements of ASTM C1116 and ASTM D7508 with the following exceptions:

- Tensile strength shall be a minimum of 65 ksi
- Modulus of Elasticity shall be a minimum of 1,000 ksi
- Cut length shall be 1.5 to 2.2 inches
- Aspect Ratio shall be 50 to 100
When Fiber-Reinforced Concrete is specified in the Contract, polyolefin fibers may be added to an approved mix design except when Macro Fiber-Reinforced Concrete is specified. If Macro Fiber-Reinforced Concrete is specified a new trial mix will be required.

PE letter must include;
- The mix design number, both the CDOT mix ID number and the supplier's mix ID number
- The brand and type of polyolefin fibers.
- The dosage of polyolefin fibers in pounds per cubic yard.
- Adjustment to the fine aggregate batch weight

Changed May, 2013
Class P Changes

Lab flexural strength requirements are at 700psi and compressive strength requirements are at 4500psi

Optional optimized gradation

Cement content can be as low as 520 lbs

CDOT now specifies compressive or flexural acceptance and is no longer the choice of the contractor.

Changed in April, 2012
Tarantula Curve

Developed by Tyler Ley from Oklahoma state

Allows for maximum consolidation with minimal vibration

Meant for slip form paving

*Credit: Tyler Ley and CP Road Map October 2014*
New Cement Types

- Type IL and IT Cements
  - 15% Limestone allowed in IL
  - 15% Limestone and 25% fly ash allowed in IT

- ASTM C 595

- Sulfate Requirements for Types of cements have been established and approved. ASTM C 1012
Super Air Meter (SAM)

- The SAM measures the quality of the air void system and not just air content
- ASTM C 457 spacing factor
- It is currently being used for informational purposes only
New Allowable Pozzolans

- Highly Reactive Pozzolans
  - HRPs are but not limited to metakaolin, rice hull ash, zirconium fume, ultra-fine fly ash, and fume from the production of 50 percent ferrosilicon (with SiO2 less than 85 percent).
  - AASHTO M321
Low Flexural Strength

- CDOT now requires a splitting tensile correlation during the mix design test batch.

- When flexural strength is indicated, at least two specimens will be tested at 3, 7 and 14 days and four specimens at 28 days.

- When flexural strength is low a core can be taken and tested for splitting tensile. The test result is then correlated to flexural strength.
Questions?