Durable Infrastructure

Concrete Best Construction Practices

Getting Your Money’s Worth From Concrete Flatwork

PRESENTED BY:
DELWARE T^2/LTAP CENTER
Delaware $T^2$ Center

- $T^2$ Centers or LTAPs located in all 50 states
- Funded by FHWA and state DOTs
- Mission – promote training, tech transfer, research implementation at local level
- Delaware $T^2$ hosted by University of Delaware, part of Delaware Center for Transportation
- Delaware $T^2$ funded by FHWA and DelDOT
Municipal Circuit Rider Program

- Delaware Center for Transportation
  - T²/LTAP Center
  - Based at University of Delaware
  - Dr. Christopher Meehan – Director, DCT
  - Dr. Earl “Rusty” Lee – T²/LTAP Program Coordinator

- Matheu J. Carter, P.E.
  - T² Engineer
  - Municipal Engineering Circuit Rider
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- Ensures you get our:
  - Newsletters
  - Urgent technical briefs
  - Upcoming training workshop notifications

- Don’t risk it! Do it today.
Concrete Flatwork Finishing Certification

Did you say “flatwork? What’s a flatwork?”
Concrete flatwork

- Examples:
  - Sidewalk
  - Curb ramps
  - Curbing
  - Patio areas
  - Concrete floors
How long should they last?

- Do you have some sidewalk or curb in your municipality that was constructed sometime prior to WWII?
  - And it still looks pretty good (all things considered)?

- Do you have some that was constructed in the past 3 years?
  - And it looks like it was strafed by the US Air Force?

- Can we agree concrete flatwork should be durable for a 25-year period if we don’t abuse it?
We’ve been having problems

- Delaware’s problem with scaling concrete is not unique
- $8 million sidewalk project in Montgomery County, Maryland
  - Showed deterioration of ~25% of the project within 1–5 years
  - Washington Post article vented the frustrations of Montgomery County officials and residents
    - Put more directly – they wigged out, became unhinged, threw a tizzy, came unglued…
      - And for good reason
What’s the problem?

- Well, it can be many things, but scaling is the elephant in the room
Concrete surface problems

- **Scaling**
  - When large portions of the concrete surface are lost

- **Mortar flaking**
  - When mortar is lost over top of a coarse aggregate

- **Popouts**
  - When top mortar, along with a portion of coarse aggregate is sheared off, leaving pitted concrete; usually caused by highly absorptive aggregate like chert

- These can happen individually or, often, together
Scaling in exterior concrete is often caused by:

- Excessive finishing
- Finishing water into the surface
  - “Blessing” the concrete
  - Working bleed water into the surface
- Too little air entrainment, especially at the surface
- Low strength concrete
- Insufficient curing
- Excessive deicing materials before the concrete has matured
This won’t last

And the public won’t be happy...

...nor should they be
The Delaware Department of Transportation (DelDOT) has sought to minimize poorly performing concrete through

- Research of mix designs
- Consultation with nation-wide experts
- Modifications to its contract specifications
“Provide an American Concrete Institute (ACI) or National Ready Mix Concrete Association (NRMCA) certified concrete flatwork technician to supervise all finishing. Provide proof of the flatwork certification to the Engineer prior to concrete placement.”

DelDOT Standard Specifications for Road and Bridge Construction, August 2016
- Cited in Sections 501, 503, 505, 610, 701, 702, 705
Long story short

- **ACI**
  - Very good
  - Very detailed; probably much more than we need finishers to go through
  - Nearest practical location ~95 miles away
  - >$600
  - Re-cert in 4 years

- **NRMCA**
  - Didn’t have a program

- **Problem**
Solution

- Henry Prenger, with LafargeHolcim, was willing to establish a NRMCA program
- Worked with DelDOT to develop
- Laser sighted on the causes of scaling

- $300–$350 per person
- Offered here in Delaware
- No expiry…it’s yours to lose
Let’s have a look
Should you adopt this too?

- Probably
- But it will be best if your Inspector is certified

- Will classes be available in 2018?
  - Perhaps
  - But only if we hear demand for it
  - So, let me know if this is something you want for your folks, your consultants, etc.
Concrete best practices

Let’s take a look at how we can better ensure durable concrete
SECTION 705 – PCC SIDEWALK, CURB RAMPS, AND SIDEWALK SURFACE DETECTABLE WARNING SYSTEM

705.01 Description.
- Construct Portland Cement Concrete sidewalk and curb ramps, install sidewalk surface detectable warning system in accordance with the Contract Documents and as directed by the Engineer.

705.02 Materials. Submit all Materials to Materials and Research Section for approval in accordance with Section 106.01. Provide Materials as specified in the following:
- Graded Aggregate Base Course, Type B Section 1005
- Portland Cement Concrete, Class B Section 1022
- 1/2 Inch Preformed Expansion Joint Material Section 1042
- Joint / Crack Sealant Material Section 1042
- Curing Compound Section 1022

PCC sidewalk and curb ramps

PCC Curb

Source: DelDOT, “Standard Construction Details,” 2017
PCC sidewalk and curb ramps

- Integral PCC Curb and Gutter

Source: DelDOT, “Standard Construction Details,” 2017
PCC sidewalk and curb ramps

- Integral PCC Curb and Gutter
  - For use at curb ramps only
PCC sidewalk and curb ramps

- Curb Ramp, Type 1 and Sections

Source: DelDOT, “Standard Construction Details,” 2017
PCC sidewalk and curb ramps

- Curb Ramps, Types 2, 3, & 4

Source: DelDOT, “Standard Construction Details,” 2017
PCC sidewalk and curb ramps

- Curb Ramp, Type 5 & Sections

Source: DelDOT, “Standard Construction Details,” 2017
PCC sidewalk and curb ramps

- Entrances

Source: DelDOT, “Standard Construction Details,” 2017
PCC sidewalk and curb ramps

- Curb Openings

Source: DelDOT, “Standard Construction Details,” 2017
PCC sidewalk and curb ramps

- Curb Opening with Sidewalk Detail

Source: DelDOT, “Standard Construction Details,” 2017
PCC sidewalk and curb ramps

- Curb Retaining Wall (reverse curb)

Source: DelDOT, “Standard Construction Details,” 2017
SECTION 705 – PCC SIDEWALK, CURB RAMPS...

705.03 Construction. Provide an American Concrete Institute (ACI) or National Ready Mix Concrete Association (NRMCA) certified concrete flatwork technician to supervise all finishing. Provide proof of the flatwork certification to the Engineer prior to concrete placement.

705.03.1 Preparation of Foundation.
- A. Excavate to width, depths and grades shown on Plans;
  - 1. When necessary remove unsuitable material and replace with approved Material
  - 2. Compact Material
- B. Place GABC to thickness shown on Plans

705.03.2 Slip-Forming. Use molds of required height, width and shape. Place concrete in accordance with Section 705.03.3 below with the exception that the expansion joints are permitted to be placed at 100 foot intervals when slipforming.

PCC sidewalk and curb ramps

- SECTION 705 – PCC SIDEWALK, CURB RAMPS...
  - 705.03.3 Fixed Forms.
    - A. Clean, wood or metal, extending the full depth of the concrete
    - B. Use composite material for radii Work;
      1. Straight and warp free, deflection no greater than 1/8 inch in 10 feet
      2. Rigid enough to resist the pressure of plastic concrete.
  - C. Placing Concrete
    1. Limitations on placing concrete during hot or cold weather as specified in Section 501.03.6;
    2. Wet GABC prior to placement of Portland Cement Concrete;
    3. Spray forms with an approved form release agent;
    4. Place concrete;
    5. Place polyurethane–bonded recycled rubber (Type IV) expansion joints full depth of sidewalk;
      a. at 20 foot intervals
      b. the beginning and end of radii
      c. both sides of all Structures or obstructions.

 SECTION 705 – PCC SIDEWALK, CURB RAMPS…

° 705.03.3 Fixed Forms.
   ° 6. Finishing;
     ° a. Use a wood or magnesium float to rub surface smooth;
     ° b. Match vertical alignment with adjacent surfaces;
     ° c. Correct surface deviations greater than 1/4 inch in 10 feet;
     ° d. Tool exposed edges in accordance with the Standard Construction Details;
     ° e. Brush perpendicular along the surface

° 705.03.4 Joints
   ° A. Construct contraction joint by tool or saw cut at 10 foot intervals when concrete is sufficiently set;
     ° 1. When sidewalk is behind the curb, align all joints in the curb to coincide with joints in the sidewalk.
     ° B. Cure sidewalk in accordance with Section 701.03.

Section 701.03 points to Section 1022

1022.01.5 Curing Materials. Use curing Materials as follows:

A. Penetrating Curing Compound with Sealer.
   - 1. Furnish a deep penetrating silane/siloxane sealer that consists of 40 percent solids by weight either in an appropriate solvent or as a stable emulsion
   - 2. The waterproofing and curing Material must be a flowable, penetrating solution capable of being applied by spray or roller
     - The applied and cured Material must not form a film or otherwise build up on the surface of the treated surface
     - Follow the manufacturer’s written instructions for surface preparation, application procedures, and application rates
   - 3. If Material is clear by nature, tint the Material with a fugitive red, blue, or green dye to enable the silane/siloxane solution to be visible on the concrete surface for at least four hours after application
     - The fugitive dye must not; however, be visible more than seven days after the application of the waterproofing Material.
   - 4. Conform to the requirements of AASHTO M148 / ASTM C 309, Type 2, Class A or B white pigmented liquid curing compounds.

B. Sheeting – conform to the requirements of ASTM C 171.

C. Burlap – Shall be plain weave cloth made of jute or kenaf, weighing 10 ounces per square yard or greater.

SECTION 705 – PCC SIDEWALK, CURB RAMPS…

705.03.5 Removal of Forms and backfilling.
- A. Remove forms and backfill when concrete has hardened sufficiently
- B. Repair all defects
- C. Remove and replace entire 10 foot long finished section of cracked or damaged sidewalk as directed by Engineer.

705.03.6 Curb Ramps
- A. Construct Curb ramps in accordance with the Contract Documents.

SECTION 705 – PCC SIDEWALK, CURB RAMPS...

705.03.7 Surface Detectable Warning System

A. Submit samples of the proposed system to the Engineer for approval prior to the start of Work.

B. Submit mortar mix formula for concrete sidewalk applications to the Engineer for approval prior to the start of Work.

C. Submit certification that the surface of the system is slip resistant using one of the following standard methods:
   1. ASTM C1028 B Determining the Static Coefficient of Friction of Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull-Meter Method
   2. ASTM D2047 B Static Coefficient of Friction of Polish-Coated Floor Surfaces as Measured by the James Machine
   3. ASTM E303 B Measuring Surface Frictional Properties Using the British Pendulum Tester
   4. VOSI V41.21–98 B Universal Specification / Test Method for Slip Resistant Walkways, in the Field and Laboratory, as measured by a Drag Type Friction Tester (Voices of Safety International (VOSI): www.voicesofsafety.com)

SECTION 705 – PCC SIDEWALK, CURB RAMPS…

705.03.7 Surface Detectable Warning System

D. Utilize the dome pattern shown in the Standard Construction Details.

E. Use one of the following material systems:

1. Precast concrete or fired clay brick paver units: manufactured with the truncated dome pattern, set on the concrete sidewalk surface.
   a. Use mortar for adhesion to the sidewalk surface and for joint filling.

2. Cast iron plates: manufactured with the truncated dome pattern, set on the concrete sidewalk surface.
   a. Anchor the plates to the sidewalk surface according to manufacturer's recommendations.

3. Stamping systems, applied membranes and ceramic tiles are not acceptable for new Work.

PCC sidewalk and curb ramps

SECTION 705 – PCC SIDEWALK, CURB RAMPS...

- 705.03.7 Surface Detectable Warning System
  - 4. The color of the final surface of the system must conform to the table below or as specified on the Plans.

<table>
<thead>
<tr>
<th>Sidewalk Surface</th>
<th>Detectable Warning System Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick</td>
<td>white, federal yellow, pale yellow</td>
</tr>
<tr>
<td>Bituminous</td>
<td>white, light gray, federal yellow, pale yellow</td>
</tr>
<tr>
<td>Concrete</td>
<td>brown, dark gray, red, brick red, black</td>
</tr>
</tbody>
</table>

The Engineer will determine the color, with a light to dark contrast, for sidewalk surfaces not listed above if not already specified on the Plans.

SECTION 705 – PCC SIDEWALK, CURB RAMPS...

705.03.7 Surface Detectable Warning System

F. P.C.C. sidewalk: Use precast concrete or fired brick paver units.

1. Construct the base material of the sidewalk section receiving the detectable warning surface at a lower elevation to allow the thickness of the concrete under the detectable warning system to be the same as the sidewalk (minimum of 6 inches).

2. Install paver units to achieve a flush surface with the surrounding ramp/sidewalk surfaces.

3. Mortar:
   a. Mix Portland cement mortar in the following proportion: one part Portland cement to three parts fine aggregate, add hydrated lime not to exceed 10 percent of the cement by weight.
   b. Dry mix the fine aggregate, Portland cement, and lime until the mixture assumes a uniform color.
   c. Add water as the mixing continues until the mortar attains a consistency that can be easily handled and spread with a trowel.
   d. Mortar that is not used within 30 minutes after water has been added cannot be used.
   e. Retempering of mortar will not be permitted.

4. Place the mortar to form a firm bond.

PCC sidewalk and curb ramps

 SECTION 705 – PCC SIDEWALK, CURB RAMPS...
 705.03.7 Surface Detectable Warning System
  • 4. Place the mortar to form a firm bond.
  • 5. Set paver units in a bed of mortar and mortar the joints.
    • a. Maintain 1/4 inch wide joints, no larger than 3/8 inch. Plastic spacers may be used.
    • b. Keep joints uniform and straight in all directions.
  • 6. Maintain clean surfaces and joints prior to applying grout.
  • 7. Bevel edges of the system with grade changes in between 0.25 and 0.50 inch with a slope no steeper than 2 to 1.
  • 8. Grade changes up to 0.25 inch may be vertical.
  • G. Brick sidewalks: Use precast concrete panels or fired brick paver units.
    • 1. Place units on the same base material and lift thickness as used under the brick sidewalk.
    • 2. Place units to achieve a flush surface with the surrounding ramp/sidewalk surfaces.

SECTION 705 – PCC SIDEWALK, CURB RAMPS...

705.04 Method of Measurement.

- **705.04.1 Sidewalk.** The quantity of sidewalk will be the measured square feet of sidewalk acceptably completed.
- **705.04.2 Sidewalk Surface Detectable Warning System.** The quantity of sidewalk surface detectable warning system will be measured as the actual number of square feet acceptably completed. Sidewalk will be measured and paid for separately.
- **705.04.3 Curb Ramp(s).** The quantity of curb ramps will be the measured square feet surface area of curb ramp acceptably completed.
  - A. The area of curb ramps will be established by the measurement of the curb, sidewalk and taper areas shown in the Standard Details.
  - B. Curb ramp(s) constructed in conjunction with the new P.C.C. sidewalk will be measured and paid for under P.C.C. sidewalk.

SECTION 705 – PCC SIDEWALK, CURB RAMPS...

705.05 Basis of Payment.

- **705.05.1 Sidewalk.** The quantity of sidewalk shall be paid for at the Contract Unit Price per square foot of sidewalk acceptably completed. Price and payment constitutes full compensation for excavation...

- **705.05.2 Sidewalk Surface Detectable Warning System.** The quantity of sidewalk surface detectable warning system shall be paid for at the Contract Unit Price per square foot. Price and payment constitutes full compensation for furnishing all Materials, ...

- **705.05.3 Curb Ramps.** The area of curb ramps shall be paid for at the Contract Unit Price per square foot. Price and payment constitutes full compensation for excavation...
  - A. Curb ramps constructed along the new P.C.C. sidewalk are paid in accordance with Item 705002 – P.C.C. Sidewalk, 6”

- Rock removal shall be paid under Section 202.
- Undercut excavation shall be paid under Section 202.
- For removal and replacement of sidewalk, P.C.C. removal shall be paid under Section 211 and saw cutting shall be paid under Section 762.

SECTION 705 – PCC SIDEWALK, CURB RAMPS…

705.05 Basis of Payment.

- P.C.C. SIDEWALK, 4” SF
- P.C.C. SIDEWALK, 6” SF
- P.C.C. SIDEWALK, 8” SF
- SIDEWALK SURFACE DETECTABLE WARNING SYSTEM SF
- CURB RAMP, TYPE 1 SF
- CURB RAMP, TYPE 2, 3 &/OR 4 SF
- CURB RAMP, TYPE 5 SF

Placing concrete

- Forms
  - Clean, wood or metal, extending the full depth

- Placement
  - Wet GABC
  - Spray forms with an approved form release agent
  - Place plastic concrete
  - Place (Type IV) expansion joints full depth
    - Also known as isolation joints
    - ≤ 20’ intervals
    - beginning and end of radii
    - sides of all structures or obstructions
Placing concrete

Temperature extremes

- Cold weather
  - Ambient air temperature, in shade, \(<35^\circ\text{F}\) (i.e., “35 and rising”)
  - Do not place on frozen grade
  - Maintain \(\geq 50^\circ\text{F}\) around the concrete for a curing period of 5 days
  - Insulating blankets, straw, polyethylene, or other protection
Placing concrete

- Temperature extremes
  - Hot weather
    - Plastic concrete > 80°F
      - Additional attention to dampening the subgrade immediately in advance of the concrete placement
      - Perform finishing, texturing, and curing operations as soon as possible [this is going to get us in trouble later; hence, avoid hot]
      - Should the pavement surface dry out to the extent that it cannot be sealed without the application of surface water, suspend placement
    - Plastic concrete > 90°F at plant – suspend placement
Finishing concrete

- **Best practice**
  - Place concrete as close to final location as you can
  - Consolidate edges; vibrate if needed
  - Strike it off (i.e., screed)
  - Seal surface with magnesium bull float
  - Then...wait
    - Plastic concrete will release bleed water and evaporate
    - Which you do not want finished into the surface
    - This can take 20 minutes or 2 hours or more
  - Then, only then, finish surface with magnesium or wood floats, tool edges, groove control joints, lightly brush surface
Practices...best?
Practices...best?
Practices...best?
Control joints
- Controls where shrinkage cracks occur
- Strike contraction joint at 10’ intervals when concrete is sufficiently set – closer better
- When sidewalk is behind the curb, align joints in the curb to coincide with joints in the sidewalk
Finishing concrete

- Construction joint
  - Formed at the end of a pour to create a neat joint for the next one
Curing concrete

- Penetrating Curing Compound with Sealer
- Sheeting
- Burlap – plain weave cloth made of jute or kenaf
- Water – drip hose, etc.
Most common curing method

- Curing compound is a wax based material
- Deep penetrating silane/siloxane sealer that consists of 40 percent solids by weight
- Conform to the requirements of AASHTO M148 / ASTM C 309, Type 2, Class A or B white pigmented liquid curing compounds
Curing compound

- Apply immediately after brooming the concrete
- Paint it white – meaning good coverage
  - We’re not looking for it to color the concrete; it will go away with time
- Best to apply in two directions for good coverage
Avoid wrong concrete

- Specify the right mix design
- Verify that the right mix was delivered
  - Happens more than you think
  - Check the delivery tickets
- Pay attention to admixtures
  - Furnace slag
  - Fly ash
  - Accelerators
- Pay attention to water
  - Don’t let them arbitrarily add water
  - Don’t let them bless the concrete
Typically, Class B

Table 1022-3. Concrete Classes for Structures

<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Maximum ( w/c ) ratio lb/lb</th>
<th>Air Content (Percent)</th>
<th>Minimum 28-day Compressive Strength ( f'_c ) (psi)</th>
<th>Maximum Permeability (Coulombs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.40</td>
<td>4.0 – 7.0</td>
<td>4,500</td>
<td>1,500</td>
</tr>
<tr>
<td>B</td>
<td>0.45</td>
<td>4.0 – 7.0</td>
<td>3,000</td>
<td>3,000</td>
</tr>
<tr>
<td>B:SF</td>
<td>0.40</td>
<td>4.0 – 7.0</td>
<td>3,500</td>
<td>2,500</td>
</tr>
<tr>
<td>C</td>
<td>0.50</td>
<td>4.0 – 7.0</td>
<td>2,000</td>
<td>3,500</td>
</tr>
<tr>
<td>D</td>
<td>0.40</td>
<td>4.0 – 7.0</td>
<td>4,500</td>
<td>1,500</td>
</tr>
</tbody>
</table>

Legend:

- A: Item 401801 - Bituminous Concrete, Superpave, Type C, 160 Gyration, PC 64-22 (Carbonate Stone)
- B: Item 760000 - Pavement Milling, Hot-Mix
- C: Item 401822 - Bituminous Concrete, Superpave, Type B, 160 Gyration, PG 64-22, Patching
- D: Item 302008 - Graded Aggregate Base Course, Type B, Patching
- E: Item 705001 - P.C.C. Sidewalk, 4” or 6” (Drives)
- F: Item 705002 - P.C.C. Sidewalk, 6” (Drives)
- G: Item 701010 - Portland Cement Concrete Curb, Type 1-B
- H: Item 701013 - Portland Cement Concrete Curb, Type 1-2
- I: Item 720050 - Galvanized Steel Beam Guardrail, Type 1-31
- J: Item 908010 - Topsoiling, 6” Depth
- K: Item 209006, Borrow, Type F
- L: Item 727004 - Chain-Link Fence, 6’ High or 6” Depth
- M: Item 727506 - Relocating Fencel
- N: Item 302007 - Graded Aggregate Base Course, Type B
Water–cement ratio, w/c

- Weight of water/weight of cement
  - Lower w/c – higher strength, durability
    - Can make the mix difficult to work with and form
    - Workability can be mitigated with plasticizers or super-plasticizers
  - Hydration – chemical reaction of water, cement hardens concrete
    - Requires ~0.35# water/# cement for full hydration
    - But a 0.35 w/c may not mix thoroughly, may not flow
    - 0.45–0.60 w/c typically used
  - DelDOT Class B mix – maximum 0.45 w/c
Water–cement ratio, w/c

- Excess water beyond hydration needs
  - Segregation of sand and aggregate from the paste
  - Excess bleedwater that can reduce strength
  - Excess shrinkage of the concrete as water leaves the concrete
    - Shrinkage cracks, visible fractures
Don’t ruin the mix

- Contractor can order a “creamier” mix and still comply with Class B mix
  - Admixtures and such at the plant...let’s move on
- This creamier mix will be easier to finish without adding water
- If the first thing the supervisor does when the truck arrives is say, “add ten gallons,” you didn’t make yourself clear at the pre-bid meeting
  - He/she didn’t even see it yet!
Don’t ruin the mix

- Contractor can add water to the truck
  - There’s an allowance in the mix design
  - There’s a way to do it properly
- But Contractor cannot exceed the water to cement ratio (0.45 lb/lb for Class B)
- And Contractor may not, may not, shall not add water to the surface of the placed concrete…ever
  - No blessing with the brush
  - No water bottle tricks, no frequent sloshing of tools
Don’t ruin the mix

Adding water…the right way

- 12.7 ...no water...shall be added after the initial introduction of water during batching, except as permitted in 12.8, and if on arrival at the job site the slump or slump flow needs to be increased to comply with the requirement stated in the purchase order.

- Unless otherwise stated, obtain the required slump or slump flow...with the addition of water, or water reducing admixture, or both.

- The maximum quantity of water or water-reducing admixture that can be added at the job site shall be determined by the manufacturer and shall not exceed the maximum water content for the batch as established by the designed mixture proportions.
Don’t ruin the mix

- Adding water…the right way
  - Adjusting the concrete mixture with water or water-reducing admixture shall be done before discharge of concrete, except when obtaining a preliminary sample in accordance with 17.6.
  - Additional water shall be injected into the mixer under pressure and direction of flow to allow for proper distribution within the mixer. After the additions, the drum shall be turned at least 30 revolutions at mixing speed. The quantity of water or water-reducing admixture added shall be recorded.
Let’s talk about salt

“Scaling happens because you used salt”
  ◦ Well, no, it probably didn’t

Properly constructed concrete can hold up to sodium chloride (“rock salt”)
  ◦ Proper mix
  ◦ Properly made
  ◦ Properly placed
  ◦ Bleedwater allowed to evaporate (or be removed)
  ◦ Avoidance of steel trowels (versus mag or wood)
  ◦ Avoid over finishing
  ◦ Cure immediately and properly
  ◦ Allow concrete to mature

In other words
If we use
Best Practices
Let’s talk about salt

- “But we use a LOT of rock salt”
- “And we use MgCl and/or CaCl”

- Ok. Well first, stop over-applying
- Next, MgCl and CaCl are common in proprietary blends and bagged salt
  - And that’s okay
  - But you should be frugal and think about when to apply it

- Come to my Winter Maintenance course
Let’s talk about slump

- What is slump?
  - A measure of the consistency of the concrete
  - A measure of the workability of the concrete

Table 1022-4. Concrete Consistencies

<table>
<thead>
<tr>
<th>Type of Work</th>
<th>Nominal Slump (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formed Elements:</td>
<td></td>
</tr>
<tr>
<td>Sections &lt; 12 inches</td>
<td>1 to 3</td>
</tr>
<tr>
<td>Sections ≥ 12 inches</td>
<td>1 to 4</td>
</tr>
<tr>
<td>Concrete placed under water</td>
<td>5 to 8</td>
</tr>
<tr>
<td>Filling for riprap</td>
<td>3 to 7</td>
</tr>
<tr>
<td>Slip Formed elements</td>
<td>0.5 to 2.5</td>
</tr>
</tbody>
</table>
Let’s talk about slump

- How do we measure slump?
  - AASHTO T 119
  - A slump cone is a right circular cone, 12” high
  - Base 8” in diameter, top 4” in diameter
  - ~$150–200
  - (Thermometer is another $10)
Let’s talk about slump

- What is the correct slump?
  - Well, DelDOT says 1–3” for sidewalk
  - Most finishers will add a ton of water if that shows up...one way or another
  - Normal concrete – you should stay ≤5” slump
  - With high range water reducer – ≤8” slump
    - Also called superplasticizer
    - A chemical additive to improve flow characteristics
    - Makes concrete more workable without adding water
  - The Contractor can make the mix “creamier” with superplasticizer without exceeding W/CM ratio
What are slag and fly ash?

- Reduce cement content
- Resist alkali–silica reaction and sulfate attack
- Fly ash assists workability and reduce water
- Slag can reduce permeability

- These don’t react quickly in the first 24 hours
- In cold weather, try to lower or eliminate these
- Concrete needs to reach about 500 psi before it can be allowed to freeze
Air entrainment

- Tiny air bubbles are entrained by use of a surfactant
  - 10–500 micrometers in diameter (0.0004–0.02”)
- Increases durability of the concrete
- Helps fight freeze/thaw
  - Excess water not needed for hydration eventually evaporates but environmental water seeps in and fills them (concrete is porous)
  - Freezing causes stress and cracks the concrete
  - The tiny air bubbles help relieve the stress

---

Tiny bubbles
In the wine
Make me happy
Make me feel fine
---Don Ho
This measures the air entrainment
We’re looking for 4–7% in Class B concrete
$1,000–$1,500
A little more complicated than a slump test
  • But not much more
Once the water is added, the clock ticks
Generally, \( \leq 90 \) minutes is permitted from the time it is produced to when it is placed
DelDOT limits this to 60 minutes
  - Unless approved admixtures are added
    - Water reducing admixtures
    - Set retarding admixtures
    - Replacement of a portion of the Portland cement with fly ash cement or slag cement

Interval between loads \( \leq 20 \) minutes or if the surface of previous loads exhibits signs of setting
More best practices

- Accepting the concrete
  - Is it the right amount? Concrete trucks carry 9–11 cubic yards
  - Is it the correct mix?
  - Is the water to cementitious ratio at or below what was specified? (Don’t let the finishers add more water than the plant held back)
  - Is the truck still within the maximum time?

- Be a good consumer
  - Don’t accept something less than you ordered
What’s on the ticket?

14.1 The manufacturer of the concrete shall furnish to the purchaser with each batch of concrete before unloading at the site, a delivery ticket containing information concerning said concrete as follows:

- Name of ready-mix company and batch plant, or batch plant number
- Serial number of ticket
- Date
- Truck number
- Name of purchaser
- Specific designation of job (name and location)
More best practices

What’s on the ticket?

- Specific class or designation of the concrete
- Amount of concrete in cubic yards
- Time loaded or of first mixing of cement and aggregates
- Amount of water added at the request of the purchaser or the purchaser’s designated representative and their initials
- Type and quantity of admixture or other adjustments made to the batch after batching
- For trucks equipped with automated water or water reducing admixture measurement and slump or slump flow monitoring equipment as defined in 12.8.1, the total amount of water or water–reducing admixture added by said equipment
- Revolution limit as determined by the manufacturer in accordance with 6.1.9
What else?

14.2 Additional information for certification purposes as designated by the purchaser and required by the job specifications shall be furnished when requested, such as:

- Reading of revolution counter at the first addition of water
- Type, brand, and amount of cement
- Class, brand, and amount of coal fly ash, or raw or calcined natural pozzolans
- Grade, brand, and amount of slag cement
- Type, brand, and amount of silica fume, admixtures, fiber reinforcement
- Source and amount of each metered or weighed water
- Information necessary to calculate the mixing water
- Maximum size of aggregate
- Mass (amount) of fine and coarse aggregate
- Ingredients certified as being previously approved
- Signature or initials of producer’s representative
More best practices

- Avoid using vapor barrier (plastic) under concrete
  - Bleed water can’t go down; all has to rise to surface
- Use only flat headed shovels and come-alongs to move concrete
  - No rakes or round shovels
  - Segregation
- Avoid steel trowels
  - Affects air entrainment
More best practices

- Delay edging and joints to after bleed water evaporates
  - The steel trowels used for these will be less detrimental later
- Joint depths should be $\frac{1}{4}$ thickness of slab
  - Use the right joint tool
- Avoid patterned concrete
  - All those joints being cut in overwork the concrete
- Stamped concrete doesn’t have the same problems
Concrete

An overview
Concrete

- Portland cement
- Water
- Filler materials
  - Aggregate (rock, sand)
  - Additives

Hydration
- Chemical reaction
- Paste hardens & binds the aggregate
Concrete

Purpose drives mix design

- **Buildings**
  - Heavy loads – strength is key

- **Roads**
  - Cold weather, deicing – durability is key

- **Water storage**
  - Need water tight concrete

- **Warehouse floor**
  - Abrasion resistance may drive design

**Big three goals**
- Strength
- Durability
- Water resistance
Concrete

Water

- Amount is key
  - Think “Goldilocks and the Three Bears”
- Sometimes, quality is critical
  - Hardness, minerals, etc.

- Properly mix/coat ingredients
- Produces hydration
- Makes mix workable

Add more water at the site?
Who decides?
How?
Concrete

Water – Amount is key

- Too little
  - Not enough paste
  - Hard to place
  - Honeycombs can result

- Too much
  - Lacks strength/durability
  - More vulnerable to cracking
  - More permeable to salts/chemicals/water (ironic)
Concrete

Water – Amount is key

- Less water we start with
  - Stronger
  - More impermeable

- W/C ratio – max 0.45 for Class B

- Slump test

- Water added at site – who decides?
  - If added at site
    - No more than “held back”
    - Only add in the drum (no spraying the shoot)
    - Mix proper revolutions per ASTM C94
Concrete

Water – ASTM C94

- If added at site – see section 12.7
  - Only if slump is less than specified
  - One time addition of water
    - As long as no concrete has been discharged
  - Can’t exceed total water content in design
  - Sufficient pressure and direction in mixture for proper distribution
  - Mix additional 30 revolutions or more
  - No water later
Concrete

How placed

- Slip form – low slump, low water content ideal
- Pumped – need more fluid
  - But adding water reduces strength and durability
  - Alternatively, use water reducer
- Tight rebar cages – often use water reducer
- Sidewalk – no additives required usually
- Concrete road patches – often use high early strength concrete
Concrete

How placed
Concrete

When placed

- Colder temperature
  - Hydration & strength gain slow or stop completely
  - Accelerating admixture called for

- Hotter temperature
  - Bleed water evaporation
  - Surface dries out/cracks
  - More water not the answer
    - Increases shrinkage cracks
  - Retarding admixture called for

Concrete setting & drying

- Air temperature
- Concrete temperature
- Humidity
- Winds
Concrete

Where placed

- Cold climates
  - Need durability against
    - Cold
    - Deicing chemicals
    - Freeze/thaw cycles
  - Concrete is porous
    - Expansion
      - Stresses
      - Cracks
    - Air entraining admixture helps
      - Air voids relieve the stress of expansion
Concrete

Types of cement (ASTM C150)

- **Type I** – general use
- **Type II** – general use with moderate sulfate resistance
  - Say for buried structures in soils with high sulfates
- **Type III** – for high early strength
  - Say for winter placement or patches
  - Similar to Type I with an accelerator
- **Type IV** – for low heat of hydration
  - Mass pours (dams, big piers like IRIB)
- **Type V** – high sulfate resistance
  - Say WWTP tanks

<table>
<thead>
<tr>
<th>Types IA, IIA, IIIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same as Types I, II, III</td>
</tr>
<tr>
<td>With added air-entraining agent</td>
</tr>
</tbody>
</table>
Concrete
Concrete

Admixtures

- Generally, these retard set time while increasing durability and strength
  - “So I got that going for me…which is nice”

- Fly ash
  - Generally, for reducing cost

- Silica fume
  - Decreases permeability (parking garage, damp spaces)

- Blast furnace slag
Concrete

Aggregates

- Strong, hard aggregate
  - Wear resistance

- Sand
  - Makes pumping and finishing easier

- Regardless
  - Clean
  - Free of chemicals that interfere with the paste
Concrete

Placing & consolidating

- Consolidate to move air voids to the surface
  - Correct amplitude & at right intervals
  - Needs vary by pour type
  - Don’t use to move concrete horizontally
  - Don’t over-vibrate
  - Settlement & non-uniformity of course aggregate
    - Less strength & durability
Concrete
Concrete
Concrete
Concrete

Finishing & Joining
- Strike off
- Bull float (or hand/Mag float)
  - Before bleed water appears
  - Finishing with bleed water on or near surface – spalling

- Excess water in mix
  - Dilutes strength
  - Makes more permeable
  - Lighter in color
Concrete

Finishing & Jointing

- As concrete sets
  - Loses water
  - Shrinks
  - Changes temperature

- Internal stresses – concrete cracks in response

- Joint is a neat, controlled crack
Concrete

Curing

- Immediately
- Retains moisture & temperature
  - Assists hydration & strength gain

Types

- Chemical compound
- Wet burlap & plastic
- Thermal blankets
- Enclosures
- Heaters from underneath
- Steam heat
Concrete

Curing

- Effect on samples
- Effect by type
Concrete

Some standards

- ASTM C31 – making and curing cylinders
- ASTM C94 – ready mix concrete
- ASTM C125 – terminology
- ASTM C143 – slump testing
- ASTM C173 – air content testing (volumetric)
- ASTM C231 – air content testing (pressure)
- ASTM C1064 – temperature testing
Concrete

Making/curing specimens

- ASTM C31 – making and curing cylinders
  - Let’s assume 4” cylinders
  - Tamping rod – \( \frac{3}{8}'' \pm 1/16'' \) (#3 rebar)
    - \( \geq 4'' \) longer than mold height
    - \( \leq 24'' \) total length
    - Tamping end rounded
    - \( \geq 6'' \) mold – 5/8” rod (#5 bar)
  - Measure
    - Slump – ASTM C143
    - Air content – ASTM C173
    - Temperature – ASTM C1064
Concrete

Making/curing specimens

- ASTM C31 – making and curing cylinders
  - Let’s assume 4” cylinders
    - Even distribution in the cylinder
    - Minimize segregation
    - 2 equal layers (for 4”)
    - Number of roddings – 25
      - Each layer
      - Bottom layer, rod through depth
      - Upper layer(s), rod through to lower layer
    - Tap outside of mold with mallet 10–15 times
    - Finish top of mold to eliminate depressions or projections >⅛”
Concrete

Making/curing specimens

- ASTM C31 – making and curing cylinders
  - Let’s assume 4” cylinders
  - Mark the molds for identification
  - Mold specimens where they will be initially cured
  - Initial cure – up to 48 hours (typically on site)
    - 60–80 °F; prevent moisture loss
    - Higher strength designs (≥6,000 psi) require 68–78 °F
  - No transportation for at least 8 hours after final set
  - Final cure – at testing facility
    - ≤30 minutes after removing molds, cure with free water on specimen surface
    - 73.5 °F ± 3.5 °F
Rebar
Rebar
Rebar
Forms
Forms
Floating/Finishing
Bleedwater

- Cardinal rule of finishing
  - Never float or trowel concrete while there's bleedwater on the surface
  - Finishing before bleedwater has evaporated can cause
    - Dusting
    - Craze cracking
    - Scaling
    - Low wear resistance
  - Working bleed–water into the surface also increases permeability
Floating/Finishing

Notice the bleed water
• Will this finish well?
Floating/Finishing

What happened here?
• Bleedwater?
• Cold temp finishing?
• Inadequate curing?
Concrete QA/QC

- QC
  - Batch plant tests (agg, water)
  - Air test
  - Slump test
- QA
  - Test cylinders
Need more?

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http://www.ce.udel.edu/dct/T2.html

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