Durable Infrastructure

Concrete Best Construction Practices

Getting Your Money's Worth From Concrete Flatwork

PRESENTED BY:

DELAWARE 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

Delaware
T^2/LTAP

UNIVERSITY OF DELAWARE · 1743 ·

DELAWARE CENTER FOR TRANSPORTATION

Municipal Circuit Rider Program

- Delaware Center for Transportation
  - T^2/LTAP Center
  - Based at University of Delaware
  - Dr. Christopher Meehan – Director, DCT
  - Dr. Earl "Rusty" Lee – T^2/LTAP Program Coordinator
- Matheu J. Carter, P.E.
  - Engineering Circuit Rider, Delaware T^2/LTAP Center

Delaware T^2/LTAP

The Preliminaries

Today's Instructor:

- Matheu J. Carter, P.E.
  - Engineering Circuit Rider
  - Back when he actually worked…
    - Heavy construction
    - Design engineer
    - Public works director

- Zoom Meeting is our platform today
  - Potential to be interactive, so join in
  - We will be recording today's session

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

Delaware T²/LTAP

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

- 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

Delaware
T²/LTAP

Something needs to change

- 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

DelDOT Standard 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
  - http://deldot.gov/information/pubs_forms/manuals/standard_specifications/index.shtml

Concrete best practices

- Let's take a look at how we can better ensure durable concrete

Placing concrete

- Forms
  - Clean, wood or metal, extending the full depth
- Placement
  - Wet GABC (graded aggregate base course, stone)
  - 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°F (i.e., “35 and rising”)
    - Do not place on frozen grade
    - Maintain ≥50°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?

Delaware
T²/LTAP

Practices…best?

Practices…best?

Delaware
T²/LTAP

Finishing concrete

- 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.

Delaware T²/LTAP

Curing compound

- 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

Delaware T²/LTAP

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

Delaware T²/LTAP

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

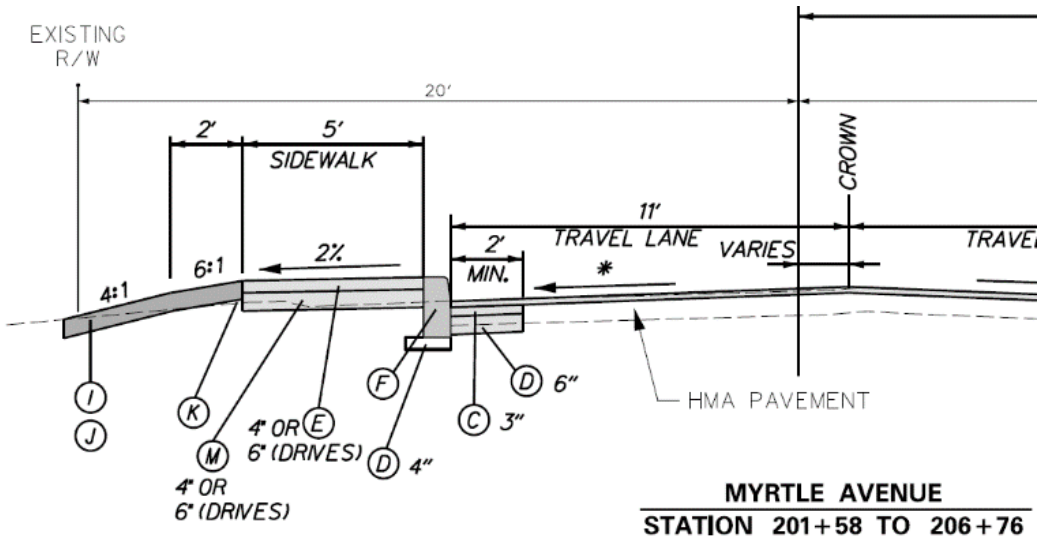
For cleaning tools only

The right mix design

- Typically, Class B

Table 1022-3. Concrete Classes for Structures

Class of Concrete	Maximum w/cm ratio lb/lb	Air Content (Percent)	Minimum 28-day Compressive Strength f'_c (psi)	Maximum Permeability (Coulombs)
A	0.40	4.0 – 7.0	4,500	1,500
B	0.45	4.0 – 7.0	3,000	3,000
B/SF	0.40	4.0 – 7.0	3,500	2,500
C	0.50	4.0 – 7.0	2,000	3,500
D	0.40	4.0 – 7.0	4,500	1,500



MYRTLE AVENUE
STATION 201+58 TO 206+76

(A) ITEM 401801 - BITUMINOUS CONCRETE, SUPERPAVE, TYPE C, 160 GYRATIONS PG 64-22 (CARBONATE STONE)

(B) ITEM 760000 - PAVEMENT MILLING, HOT-MIX

(C) ITEM 401822 - BITUMINOUS CONCRETE, SUPERPAVE, TYPE B, 160 GYRATIONS, PG 64-22, PATCHING

(D) ITEM 302008 - GRADED AGGREGATE BASE COURSE, TYPE B, PATCHING

(E) ITEM 705001 - P.C.C. SIDEWALK, 4"
OR
ITEM 705002 - P.C.C. SIDEWALK, 6"

(F) ITEM 701010 - PORTLAND CEMENT CONCRETE CURB, TYPE 1-8

(G) ITEM 701013 - PORTLAND CEMENT CONCRETE CURB, TYPE 1-2

(H) ITEM 720050 - GALVANIZED STEEL BEAM GUARDRAIL, TYPE 1-31

(I) ITEM 908010 - TOPSOILING, 6" DEPTH

(J) ITEM 908014 - PERMANENT GRASS SEEDING, DRY GROUND

(K) ITEM 209006, BORROW, TYPE F

(L) ITEM 727004 - CHAIN-LINK FENCE, 6' HIGH
OR
ITEM 727506 - RELOCATING FENCE

(M) ITEM 302007 - GRADED AGGREGATE BASE COURSE, TYPE B

Delaware T²/LTAP

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

Designation: C94/C94M – 17a

Standard Specification for Ready-Mixed Concrete[1]

- 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

Designation: C94/C94M – 17a

Standard Specification for Ready-Mixed Concrete[1]

- 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

Delaware
T²/LTAP

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 <u>when</u> to apply it
- Come to our Winter Maintenance course

Let's talk about slump

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

Table 1022-4. Concrete Consistencies

Type of Work	Nominal Slump (inches)
Formed Elements:	
Sections< 12 inches	1 to 3
Sections ≥ 12 inches	1 to 4
Concrete placed under water	5 to 8
Filling for riprap	3 to 7
Slip Formed elements	0.5 to 2.5

Delaware T²/LTAP

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

Air content meter

- 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

Time

- Once the water is added, the clock ticks
- Generally, ≤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 ≤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

More best practices

Designation: C94/C94M – 17a

Standard Specification for Ready-Mixed Concrete[1]

- 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

Designation: C94/C94M – 17a

Standard Specification for Ready-Mixed Concrete[1]

- 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

More best practices

Designation: C94/C94M – 17a

Standard Specification for
Ready-Mixed Concrete[1]

- 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 ¼ 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

Overworked joints

Delaware
T²/LTAP

Concrete

- An overview by the Portland Cement Association
- https://youtu.be/9Xti2cifAsc
- ~18 minutes
- It's a bit old, but the fundamentals are still valid
- It's worth a viewing

- In the next 20 or so slides, we'll capture the high points

Concrete

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

} Paste/glue

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

Delaware T²/LTAP

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

Designation: C94/C94M – 17a

Standard Specification for Ready-Mixed Concrete[1]

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

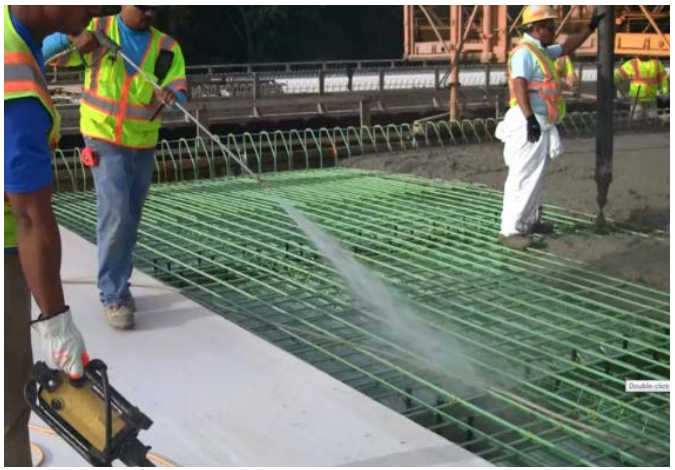
Delaware
T²/LTAP

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

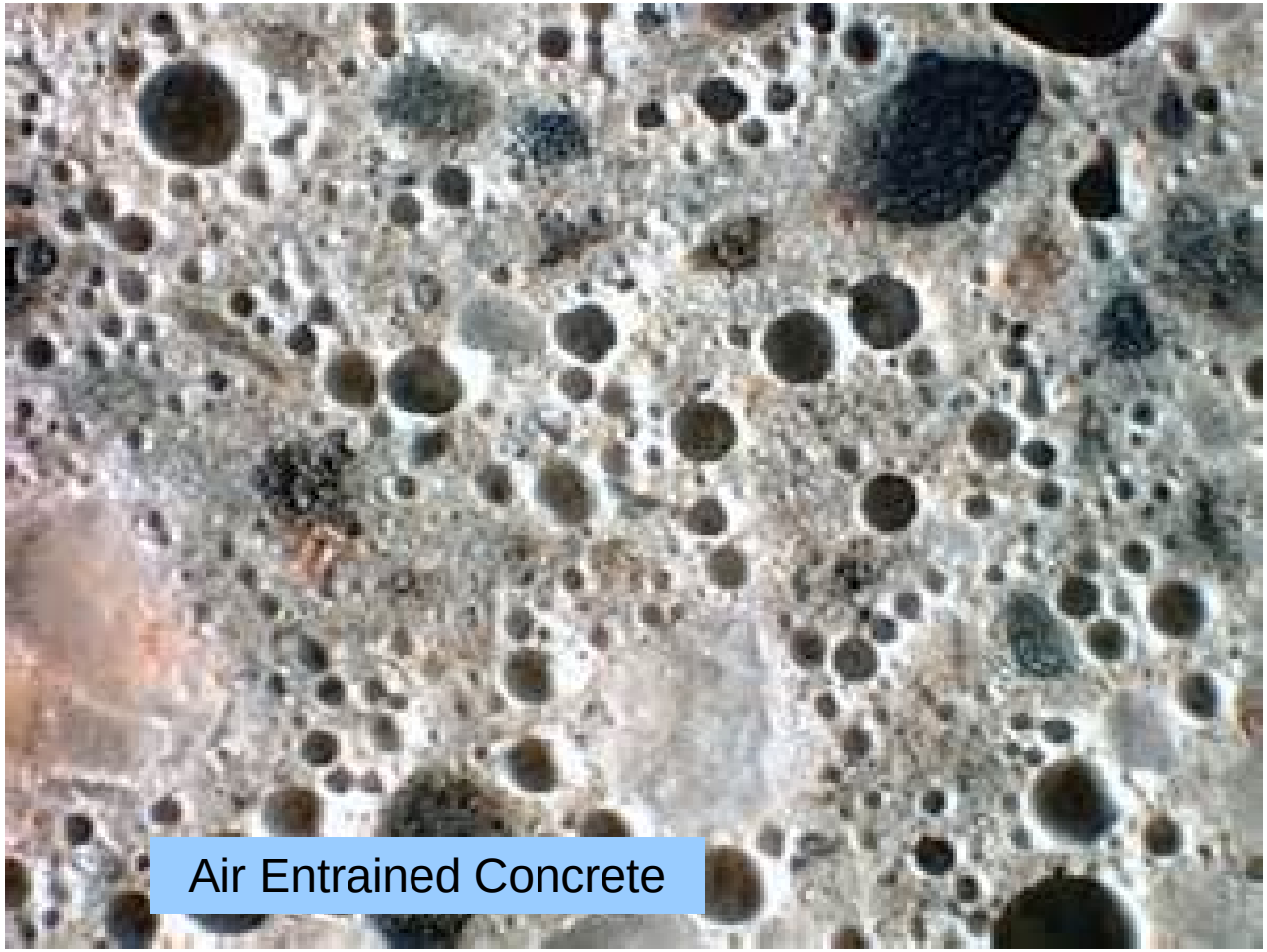
Types of cement (ASTM C150)

- 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

Types IA, IIA, IIIA

- Same as Types I, II, III
- With added air-entraining agent

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

Delaware T²/LTAP

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

Delaware T²/LTAP

Concrete

Finishing & Jointing

- As concrete sets
  - Loses water
  - Shrinks
  - Changes temperature
- Internal stresses – concrete cracks in response
- Joint is a neat, controlled crack

Concrete

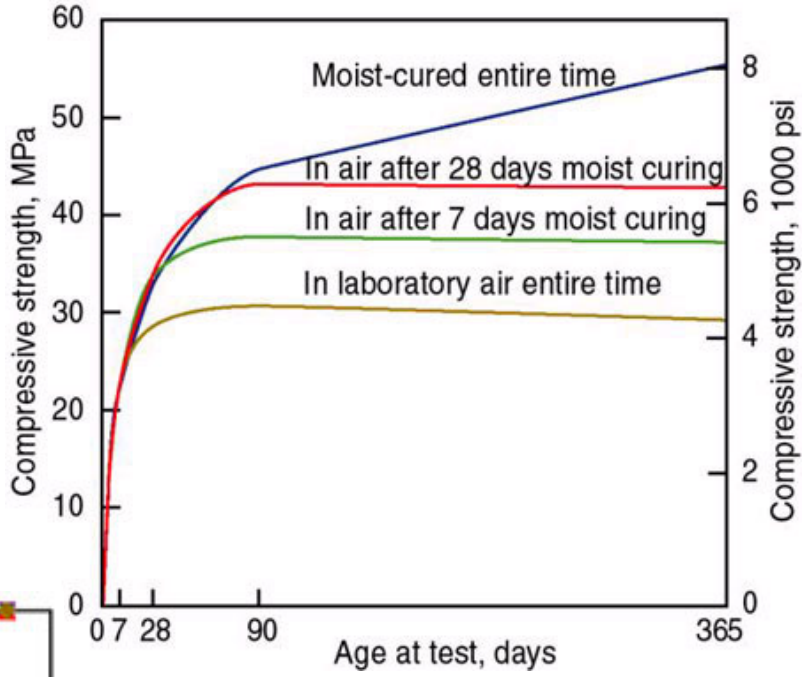
Curing

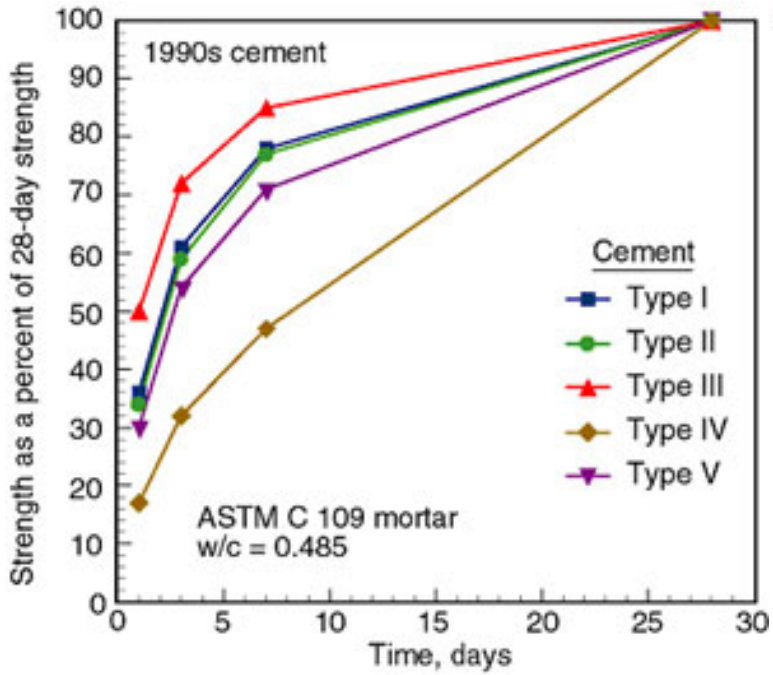
- Immediately
- Retains moisture & temperature
  - Assists hydration & strength gain
- Types
  - Chemical compound
  - Wet burlap & plastic
  - Thermal blankets
  - Enclosures
  - Heaters from underneath
  - Steam heat

Concrete

Curing

- Effect on samples
- Effect by type





Delaware T²/LTAP

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

Designation: C31/C31M – 17

Standard Practice for
Making and Curing Concrete Test Specimens in the Field[1]

Making/curing specimens

- ASTM C31 – making and curing cylinders
  - Let's assume 4" cylinders
  - Tamping rod – ⅜"± 1/16" (#3 rebar)
    - ≥4" longer than mold height
    - ≤24" total length
    - Tamping end rounded
    - ≥6" mold – 5/8" rod (#5 bar)
  - Measure
    - Slump – ASTM C143
    - Air content – ASTM C173
    - Temperature – ASTM C1064

Delaware T²/LTAP

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"

TABLE 2 Method of Consolidation Requirements

Slump in. [mm]	Method of Consolidation
≥ 1 [25]	rodding or vibration
< 1 [25]	vibration

TABLE 3 Molding Requirements by Rodding

Specimen Type and Size	Number of Layers of Approximately Equal Depth	Number of Roddings per Layer
Cylinders:		
Diameter, in. [mm]		
4 [100]	2	25
6 [150]	3	25
9 [225]	4	50

Concrete

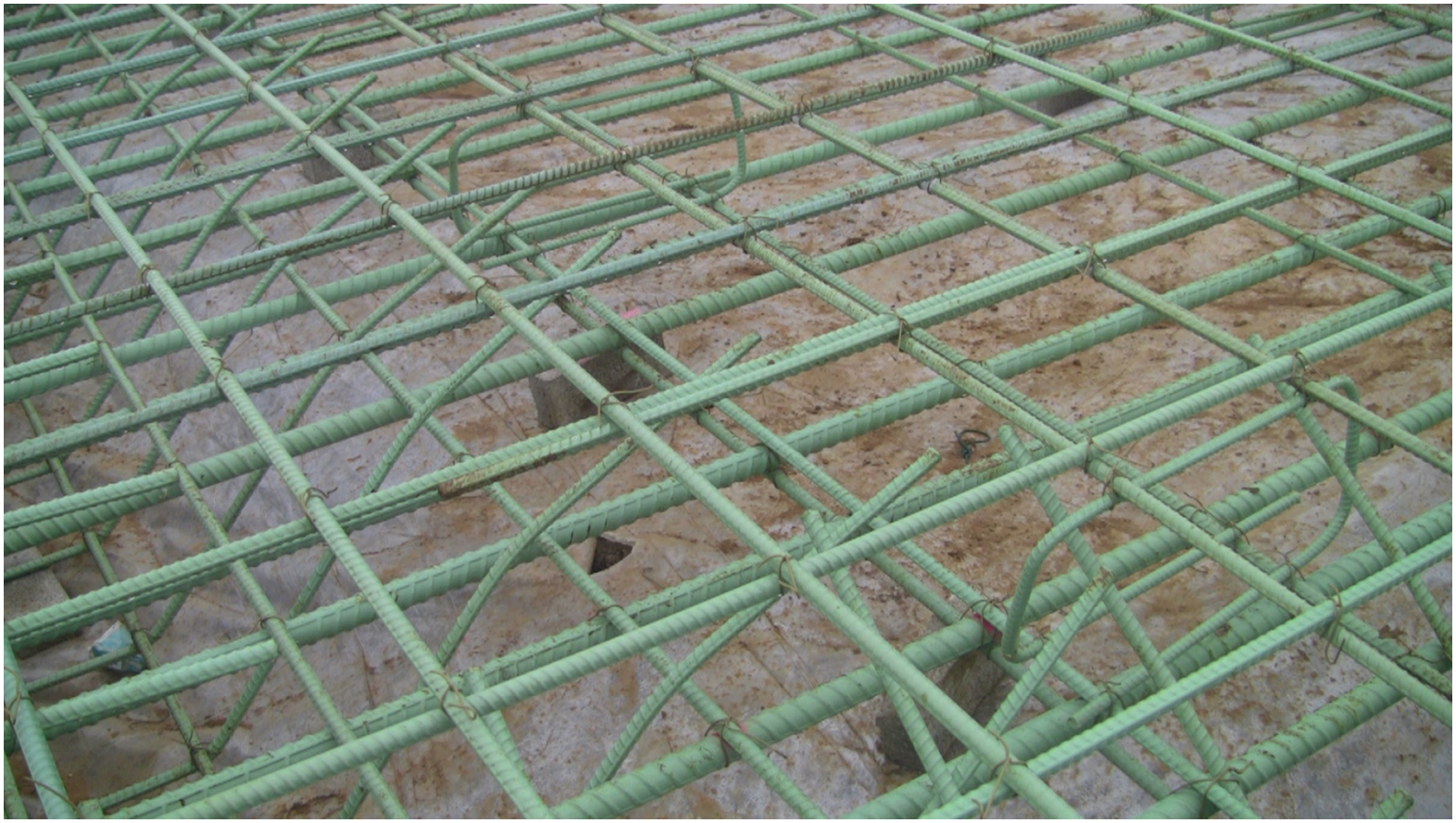
Making/curing specimens

- 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

Delaware T²/LTAP

Rebar

Rebar



Rebar

Forms

Forms

Floating/Finishing

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?

Matt Carter
Municipal Engineering Circuit Rider
Delaware T² Center
matheu@udel.edu
(302) 831-7236

https://sites.udel.edu/dct/t2-center/

Delaware
T²/LTAP