Virginia Department of Transportation

Hydraulic Cement Concrete

2018 Bridge Construction Inspection School

Chaz Weaver, PE, PEM
VDOT Staunton District
Materials Engineer

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How Important is Inspection?

According to the American Society of Civil Engineers*:

10% of issues are from design
10% are materials-related
10% are acts of God and
70% are workmanship!

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Observer – Expectancy Effect

If you know I'm going to test, you'll make sure it's right

If you think I might test, you'll try to do it right

If you know I won't test, you'll just get it done

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History of Concrete

300 BC – Romans used pozzualana, found near Pozzouli (near Naples, Italy)

1756 – John Smeaton, British engineer, rediscovers hydraulic cement from testing mortar

1824 – Joseph Aldin, bricklayer and mason in Leeds, England, patented Portland cement – named after the stone quarried on Isle of Portland off Britain's coast

1871 – 1st US Portland cement plant at Coplay, PA

1889 – 1st reinforced concrete bridge built

1891 – 1st US concrete street at Bellefontaine, OH

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History of Concrete

1913 – 1st Ready-Mix concrete
1916 – Portland Cement Association founded
1917 – ASTM standard for concrete
1936 – Hoover Dam completed
1940 – Air-entrained concrete
1970 – Fiber-reinforced concrete
1970s – Silica Fume used in concrete
1986 – Concept for self-consolidating concrete
1990s – Low-permeability concrete studies

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Characteristics of Concrete

Strength
Set time and strength gain
Permeability
Workability
Durability

~~**Fracture Toughness**~~
~~**Creep**~~
~~**Fatigue Behavior**~~

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Types of Concrete

Self-Consolidating Concrete (SCC)

Lightweight Concrete

Low Shrinkage Concrete

Ultra-High Performance Concrete (UHPC)

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Concrete Constituents

Cement – Calcium, Silica, Alumina and Ferrite

- Typically Type I/II – Most common
- Type III – Higher early strength
- Type IV – Mass concrete (lower heat of hydration)
- Type V – High sulfate resistance
- Blended – IS, IP, IT, IL

Aggregates – Well-graded

- Lower cement content
- Lower water demand
- Reduce drying shrinkage

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Concrete Constituents

Admixtures

- **Air-Entrainment**
- **Water-Reducing (Plasticizers)**
- **Retarder**
- **Accelerator**
- **Corrosion Inhibitor**
- **Pozzolans**
  - Fly Ash: residue from coal-burning plants
  - Ground Granulated Blast Furnace Slag: top of furnace ladle
  - Silica Fume: solidified silicon dioxide vapor
  - Reduce permeability
  - Reduce ASR
  - Reduce Sulfate Attack

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Durability

Freeze-Thaw

- **Improper Handling**
- Air-Entrainment
- **Poor cold weather placement**

Alkali-Silica Reaction (ASR)

- **PCC contains N_2O and K_2O, which react with silica in the aggregate to form silica gel. This gel aggressively absorbs water, which causes the pressure that causes cracking**

Low alkali cements

Photo: FHWA

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Concrete Scaling

What causes this?

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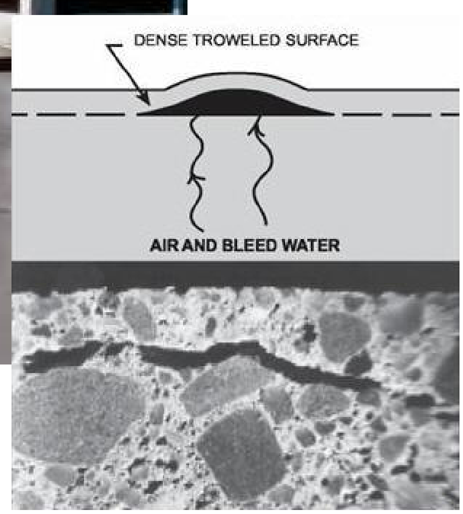
Concrete Scaling



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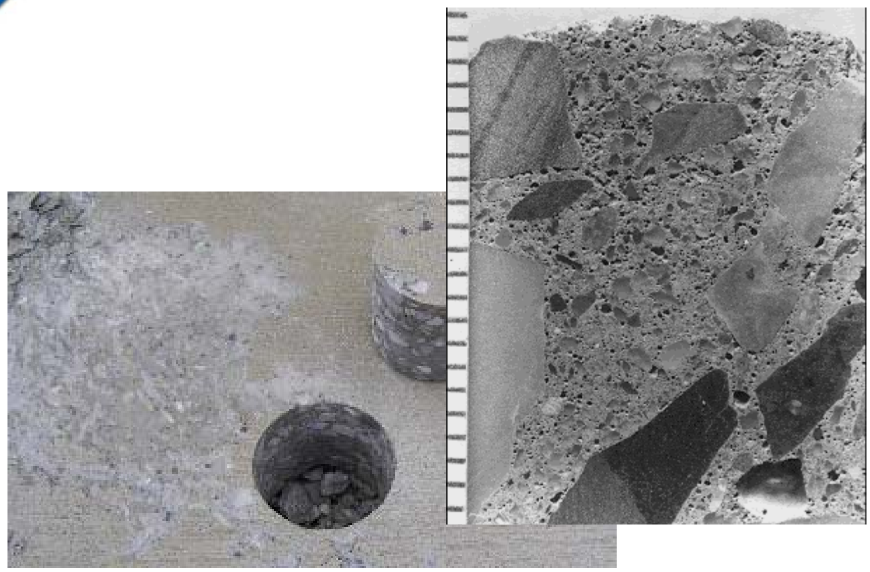
Concrete Scaling



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Durability

Sulfate Attack

- C_3A reacts with sulfate ions, creating ettriginite crystals that expand and cause cracking, OR
- CH_2 crystals turn to gypsum (lower strength)

Low Permeability Concrete

Corrosion of Steel

- Water causes steel to rust, which expands it – volume increase cracks concrete, allowing more water intrusion

Low Permeability Concrete/
CRR Steel

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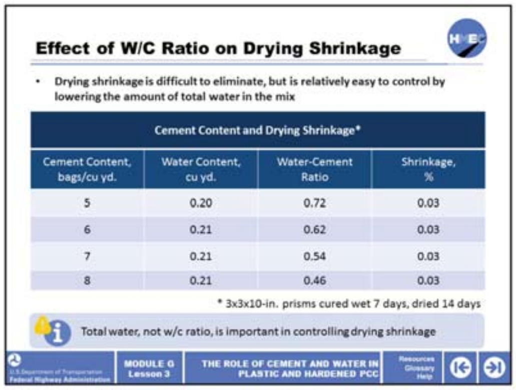
Shrinkage

Drying Shrinkage

Water not needed for hydration evaporates

- Should take 90+ days
- Total water, not water/cement ratio

Don't add water at site



Effect of W/C Ratio on Drying Shrinkage

- Drying shrinkage is difficult to eliminate, but is relatively easy to control by lowering the amount of total water in the mix

Cement Content and Drying Shrinkage*

Cement Content, bags/cu yd.	Water Content, cu yd.	Water-Cement Ratio	Shrinkage, %
5	0.20	0.72	0.03
6	0.21	0.62	0.03
7	0.21	0.54	0.03
8	0.21	0.46	0.03

* 3x3x10-in. prisms cured wet 7 days, dried 14 days

Total water, not w/c ratio, is important in controlling drying shrinkage

MODULE G Lesson 3 | THE ROLE OF CEMENT AND WATER IN PLASTIC AND HARDENED PCC

Photo: FHWA

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Shrinkage

Plastic Shrinkage

Evaporation rate (humidity, air temperature, concrete temperature and wind velocity)

Cover quickly; Fogging is not intended to dampen surface!

Photo: FHWA

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Shrinkage

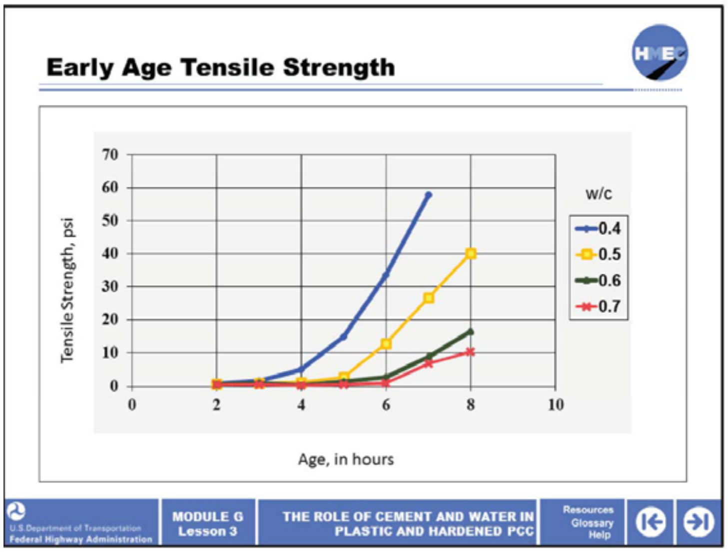

Photo: FHWA

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Shrinkage

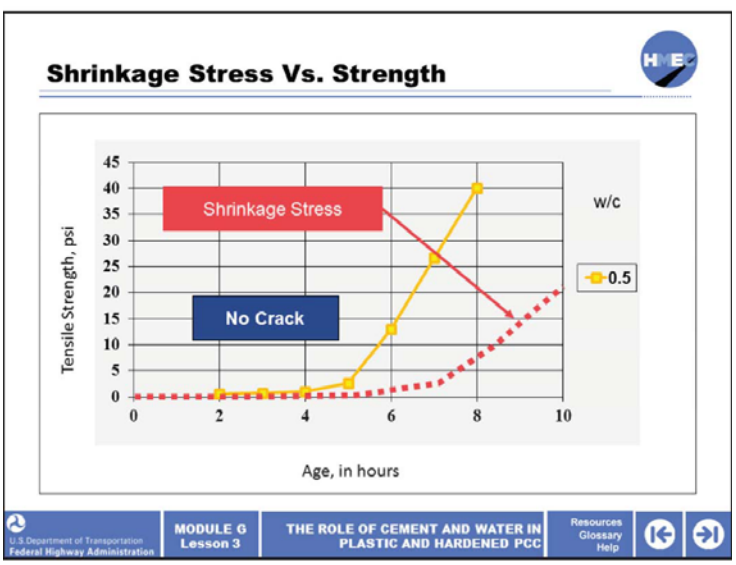

Photo: FHWA

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Shrinkage

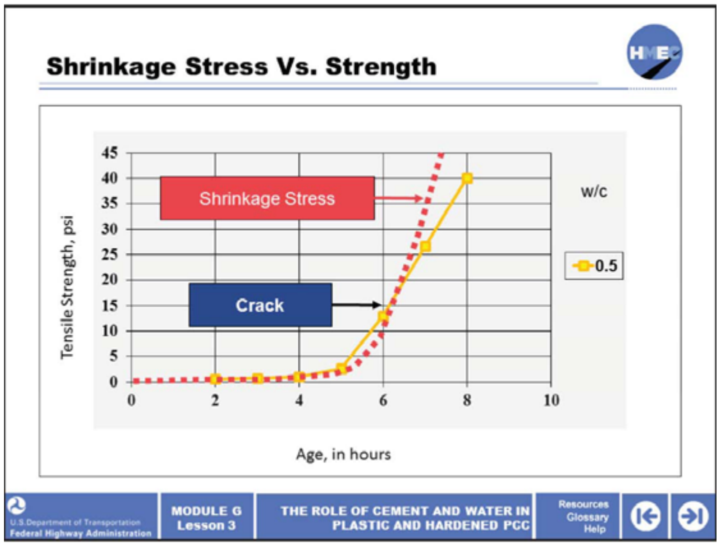

Photo: FHWA

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Cracking = High Permeability

Photos: VDOT

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VDOT Concrete

Approved Plant

Approved Job Mix Formula *for that application*

- **Low-Shrinkage, Low Permeability, Lightweight, Non-Polishing, Self-Consolidating, etc.**
- **Include JMF number with C-25 Source of Materials**
- **Why wait?**
  - Strength/Permeability/Shrinkage tests take 28 days!
  - Should be discussed at Pre-Construction Meeting

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VDOT Concrete

Trucks

- **Self-Inspection**
- **Check anyway**
- **Any signs of contamination, clumping, etc. – reject load!**

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Concrete – Planning

- **Delivery Rate (number of trucks)**
  - **Haul time**
  - **Additional concrete is typically necessary**
    - Stay-in-Place forms
    - Crown/overhangs
    - Rejected loads
    - Poor yield
- **Method of Placement (pump?)**
- **Backup Plan – Placement and Curing**
  - **Equipment Breakdown**
    - Spare Parts?
  - **Cold Joints**
  - **Materials must be on-site!**

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Concrete – Planning

- **Weather – Hot or Cold**
  - **Have an acceptable plan!**
  - **Cannot simply blow hot air (evaporation)**
- **Location for testing**
  - **Safe but efficient**
- **Location for cylinder curing box**
  - **Continuous Recording Thermometer**

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Concrete – Temperature

Temperature requirements are written in stone.

- **No legal thing as "at contractor's risk" on VDOT project!**

Minimum 40° F for all concrete

- **Bridge Deck curing – minimum 50° F for 72 hours, then minimum 40° F for duration of curing period**
- **2016 R&B Specs Section 404.03(l) for protection of concrete**

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Concrete – Temperature

Different applications have different maximum temperatures

- **Incidental Items – 95° F**
- **Paving – 95° F**
- **Bridge Decks – 85° F**
- **Retaining Walls and Other – 90° F**

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Concrete – Temperature

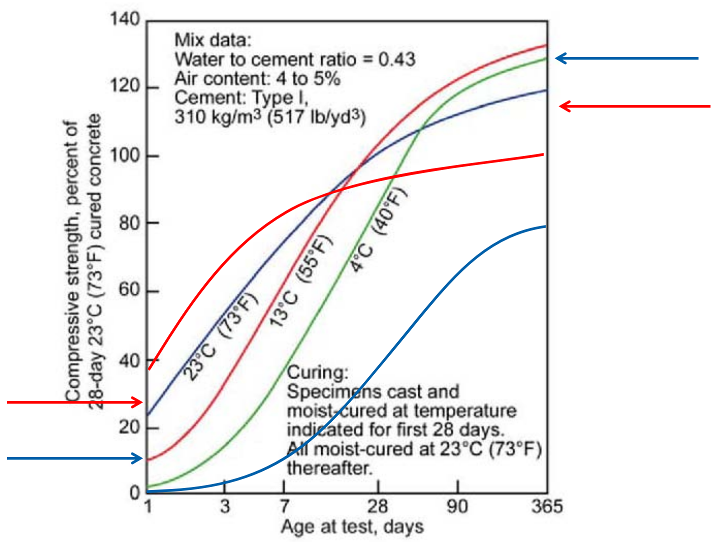

Photo: FHWA

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Concrete – Temperature

Cold Weather

- Mix water heated / Aggregate heated
- Accelerator to help hydration
- NO FREEZING.

Hot Weather

- Mix water cooled / Aggregate misted / Ice chips
- Retarder to slow hydration

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Concrete – Re-tempering

As temperature rises, air entrainment and slump suffer

- Air-entraining admixture can be added on-site
- Water reducer (plasticizer) can be added to increase slump
  - In lieu of adding water! Water decreases strength
  - Superplasticizer increases slump without reducing strength

Re-tempering requires thorough mixing!

- 70 revolutions; 14-20 revolutions/minute

Admixtures should not be added together!

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Concrete – Inspection

VDOT materials certification is required

Are you checking the tickets?

- Don't rely on the plant to do this for you!
- Batch weights should be included
- Should closely match TL-28

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Concrete – Testing

Are you testing each load?

- **OK if mix delivered is consistent**
  - **Unit Weight**
  - **Air Entrainment**
  - **Slump**
  - **Temperature**
- **If there is any reason to suspect an issue, test it!**
  - **Penalties can only be applied to loads tested**
  - **Trust, but verify**
  - **Make additional cylinders**
  - **Document where each load went**

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Concrete – Placement

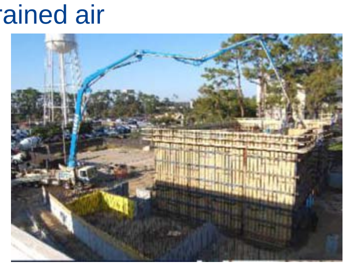
Pumping

Horizontal discharge should be used at the end

- Limits segregation and loss of entrained air

Bucket

Minimal impact on properties



Belts

Minimal impact on properties

Direct Discharge

Segregation increases as slump increases

Air-entrainment OK as long as drop height minimal

Tremie

Air-entrainment can be reduced

Segregation can be reduced by controlling drop height

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Concrete – Placement

Proper vibration means:

- ***Vertical* insertion of the vibrator;**
- **In the case of wet on wet lifts, the vibrator should penetrate the existing lift;**
- **Not using the vibrator to move or drag the concrete horizontally;**
- **Positioning the vibrator so the zone of influence of the vibrator insertions overlap;**
- **Not contacting any embedded steel; and**
- **Vibrating only long enough for uniform consolidation (usually 5 to 15 seconds)**

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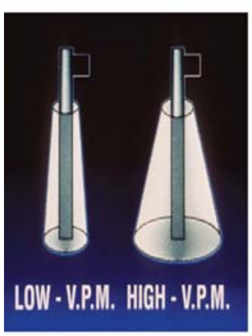
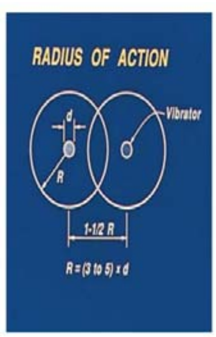
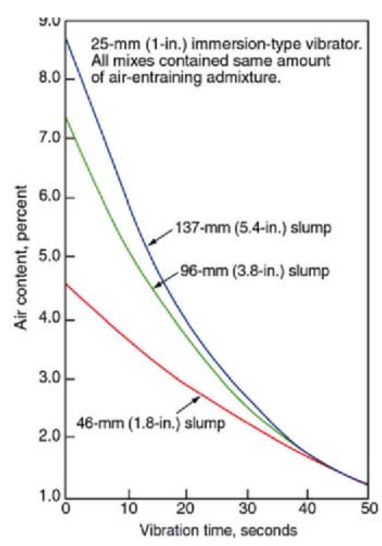
Concrete – Placement







Photos: FHWA

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Concrete – Curing

Various methods are allowed, but curing must begin directly after finishing

Proper curing improves:

- Strength
- Permeability
- Durability

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Deck Overlays

Surface Preparation

Photos: VDOT

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More Training

TC3 Courses
(VDOTU and AASHTO)

Bridge Inspection Safety
Plan Reading – Bridge Plans
Drilled Shaft Inspection Tutorial
Construction of MSE Walls
Self-Consolidated Concrete
Concrete Series

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Thanks!

Questions?

Chaz Weaver, PE, PEM
540.746.8801
chaz.weaver@vdot.virginia.gov