Durable Concrete Mixtures

ACI 201.2R-16 Guide to Durable Concrete

• The design, detailing, and execution of concrete to resist weathering action, chemical attack, abrasion, and other processes of deterioration over its intended service life will determine its durability.

• Durable concrete will retain its original form, quality, and serviceability when exposed to its environment.

• Deterioration mechanisms are either chemical or physical in nature and may originate from within the concrete, or may be the result of the external environmental exposure.

Distress

Snow Removal Products

Depress freezing point

Anti-icing
• Prevents snow & ice from bonding to the roadway
• Easier for plows to clear roads when combined with de-icers
• Applied hours before a storm as part of a pretreatment strategy to be proactive

De-icing
• Breaks the bond of already existing snow and ice
• Products dissolve downward & penetrate until they reach the pavement
• Melt ice & snow so it may be easily removed by mechanical means (plows)
• Not necessarily intended to clear every bit of ice and snow on the road

Source: CDOT Website
De-icers and Anti-icers

- Magnesium Chloride (MgCl₂) and Calcium Chloride (CaCl₂)
  - React with Calcium Hydroxide (Ca(OH)₂) in paste
  - Forms Calcium Oxychloride (CaOXY)
  - Expands ~300%
  - Use of SCM’s reduce the amount of calcium hydroxide available and reduce permeability

Deicer Distress Mechanisms

Physical
- Freeze-thaw deterioration
  - Increased level of saturation
  - Inadequate air void system
  - High w/cm ratio

Chemical
- Phase change – calcium hydroxide and calcium chloride combine to form calcium oxychloride
  - Highly expansive

Historically concrete pavements are designed and accepted based on strength, slump, and air.

Thought processes...
- More Cement = More Strength
- Strength is everything
- Slump indicates quality

FALSE
Performance vs. Prescriptive

- Bring in new testing technologies while phasing out outdated methods
- Focus on end results and long term durability

PEM Goals

- Improved durability
- Lower materials cost
- Encourage Innovation
- Lower environmental impact
- Prevents excessive over-design
- Smoother pavements

PEM Goals


What actually matters?

- Transport Properties/Permeability
- Aggregate Stability
  - ASR Susceptibility
  - Cold Weather Resistance
- Air Content
- Shrinkage
- Strength
- Workability

COMPONENTS OF CONCRETE

Cement

- ASTM C150 – Portland Cement
- ASTM C595 – Blended Hydraulic Cements
- ASTM C1157 – Performance of Hydraulic Cements

Cement Content

- Excess has a negative effect on:
  - Permeability
  - Shrinkage
  - Cost
- Optimum depends on:
  - Aggregate type
  - Gradation
  - Aggregate Shape
- Performance Specs do not specify minimum or maximum cement contents
Supplementary Cementitious Materials

- Class C Flyash
- Class F Flyash
- Class N Natural Pozzolans
- Slag Cement

Why Class F Flyash?
- Reduced Cement Paste and content
- Decreased Permeability
- Increased Workability
- ASR Mitigation
- Sulfate Resistance
- Slows strength gain and initial set
- Replace cement, not in addition

Supply of Class F

- Byproduct from coal fired power plants
- Changing environmental regulations
- Less coal fired more natural gas power production
- Lower power usage during pandemic
- Logistics of distribution, getting it to the right place at the right time
- Class C is not an adequate replacement
  - Does reduce permeability, but not as greatly
  - Does not provide same ASR mitigation, sulfate resistance

New products in the Region

- Class N Natural Pozzolans
- ASTM C618
- Available locally
  - Plant in Pueblo
- Provides many of the same properties as Class F
  - ASR Mitigation, Sulfate Resistance, Decreased permeability, increased workability
- Used in same dosage as Class F Flyash
  - 20% cement replacement

- Slag Cement
- ASTM C989
- Byproduct from Iron Blast Furnaces
- Starting to be used in paving markets
- Provides the same properties as Class F
  - ASR Mitigation, Sulfate Resistance, Decreased permeability, increased workability
- Higher dosages required
  - 30-50% cement replacement

Relationship of Strength to w/cm

Concrete is a “hard sponge”
- More water
- More porous sponge
- Increased Permeability

Concrete strength
- More water
- More separation between cement particles
- Reduced strength

Benefits of Optimized Aggregate Gradations

- Increased workability
- Reduced segregation
- Reduced cracking
- Reduced cement content

Optimized Aggregate Gradations

0.45 Power Curve

www.tarantulacurve.com
Admixtures
- Air Entrainment
- Freeze/Thaw Durability
- Water Reducers
  - Low, Mid, High Range
- Stabilizers
  - Slows initial hydration
- Accelerators
  - Accelerates hydration

Air Void Systems
Why?
- Smaller is more stable
- Less reduction in strength
- Better spacing → More durability

Air Entrained for Freeze/Thaw Protection
- Effect of Freeze-Thaw Cycles
- "Lower" w/cm also required

Super Air Meter (SAM)
- Two rounds of increasing pressures
  - 14.5, 30, and 45 psi
- Difference between 2 runs is SAM Number
- Tests spacing and stability of air void system

ASR Susceptibility
- ASTM C1260
  - Testing of individual aggregates
  - 14 day expansion
- ASTM C1567
  - Testing of mix as a whole: cement, SCM, and aggregates must be included
  - Ensures SCM will mitigate reactive aggregates

Permeability
- Directly related to long-term durability
- Paste content
- How do we lower permeability?
  - Low w/cm ratio
  - Use Supplementary Cementitious Materials
  - Optimized gradations
Surface Resistivity

- Tests permeability
- Instant results on hardened concrete
- Non-destructive
- Requirements at 28 days
  - CDOT requirement 12 kΩ-cm at 28 days
- Alternating current is applied to the outside electrodes and the voltage between the middle two electrodes is used to determine the resistance

Workability

- Slump Test?
- Box Test
  - Response to Vibration
- Factors in Workability
  - Aggregate Gradation and shape
  - Paste Content
  - Admixtures

Slump- What is it good for

- CONSISTENCY!!
- What it is not
  - Indication of water in the mix
  - Indication of workability

Box Test

- Should only be used for QC purposes
- Response to vibration
- Ability of grout to fill voids
- Ability of the concrete to hold an edge

Strength- Maturity

- Real time strength of concrete
- Cost effective
- Maturity Curves should be developed with every mix design
- Can be monitored remotely
  - Depends on Brand
- Non-destructive, easy to interpret

Smoothness

- Mix properties have equal effect on smoothness as the paving process
- Optimized gradations
  - Reduced warp/curl
- Workability
  - Less hand finishing, let the equipment do its job
Questions?

Resources

• National Concrete Pavement Technology Center
  https://cptechcenter.org/performance-engineered-mixtures-pem/
• FHWA- Mobile Concrete Technology Center