

Durable Concrete Mixtures



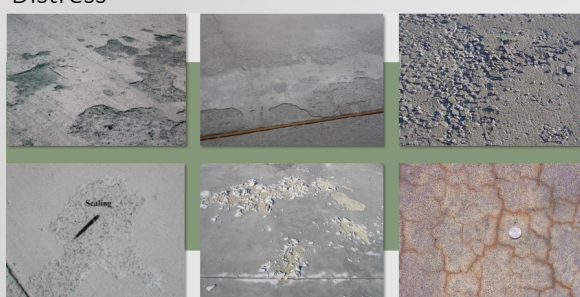

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ACI 201.2R-16 Guide to Durable Concrete

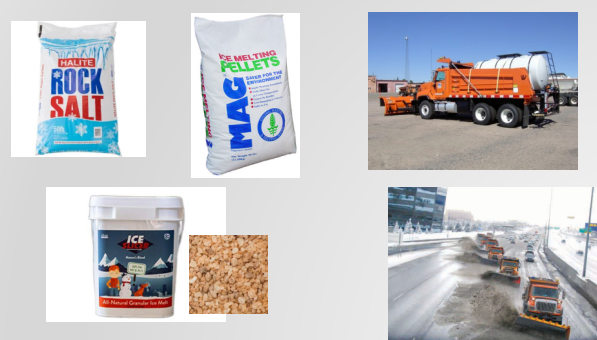
- The design, detailing, and execution of concrete to **resist** weathering action, chemical attack, abrasion, and other **processes of deterioration over its intended service life** will determine its durability.
- Durable concrete will **retain its original form, quality, and serviceability** when 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**.

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Distress



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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

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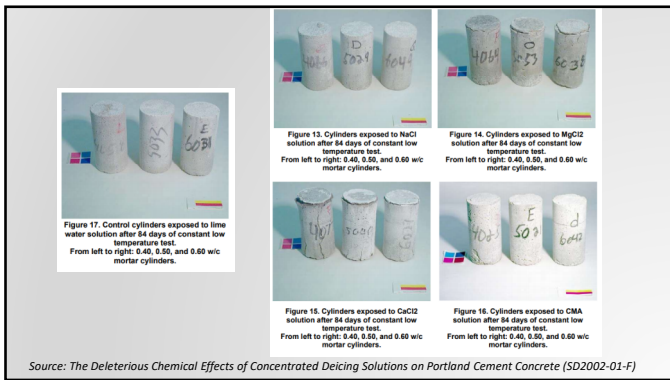
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Deicer Distress Mechanisms

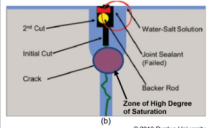

Physical

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





Source: FHWA-HIF-17-008

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De-icers and Anti-icers

- Magnesium Chloride ($MgCl_2$) and Calcium Chloride ($CaCl_2$)
 - 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



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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



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Performance vs. Prescriptive

- Bring in new testing technologies while phasing out outdated methods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

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PEM Goals

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

More information: <https://cptechcenter.org/performance-engineered-mixtures-pem/>

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What actually matters?

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

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COMPONENTS OF CONCRETE

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Cement

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

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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

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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

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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



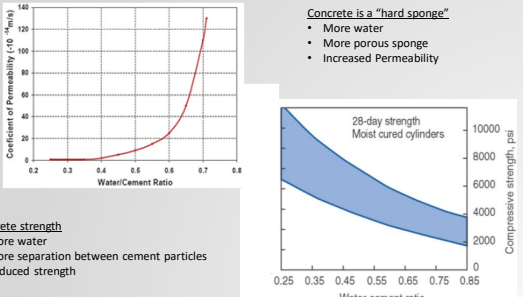
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New products in the Region

- 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

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Relationship of Strength to w/cm



Concrete is a "hard sponge"

- More water
- More porous sponge
- Increased Permeability

Concrete strength

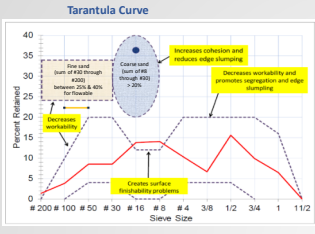
- More water
- More separation between cement particles
- Reduced strength

28-day strength Moist cured cylinders

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Benefits of Optimized Aggregate Gradations

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

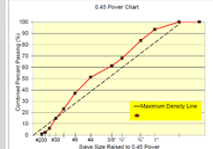


www.tarantulacurve.com

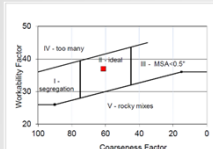
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Optimized Aggregate Gradations

0.45 Power Curve



Shilstone Coarseness Factor



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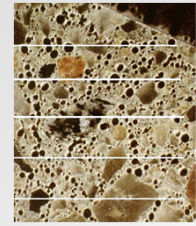
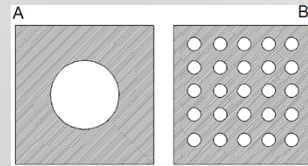
Admixtures

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



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Air Void Systems



Why?

- Smaller is more stable
- Less reduction in strength
- Better Spacing -> More durability

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Air Entrained for Freeze/Thaw Protection

- Effect of Freeze-Thaw Cycles
- "Lower" w/cm also required



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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



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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



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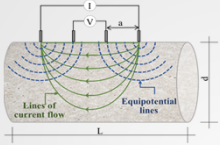
Permeability

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

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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

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Workability

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



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Slump- What is it good for

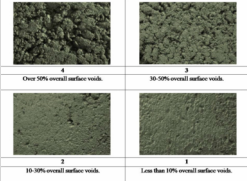


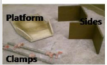



- CONSISTENCY!!
- What it is not
 - Indication of water in the mix
 - Indication of workability

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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

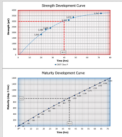




	Step 1	Gather the different components of the Box Test.
	Step 2	Construct box and place clamps tightly around box. Hand scoop mixture into box until the concrete height is 9.5" (241.3 mm).
	Step 3	Insert vibrator downward for 3 seconds and upward for 3 seconds. Remove vibrator.
	Step 4	After removing clamps and the forms, inspect the sides for surface voids and edge chipping.

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Strength- Maturity


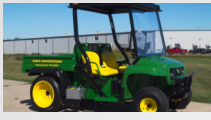

- Real time strength of concrete
- Cost effective
- Maturity Curves should be developed with every mix design
- Can be monitored remotely
 - Depends on Brand
- Non-destructive, easy to interpret

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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

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Questions?

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Resources

- National Concrete Pavement Technology Center
<https://cptechcenter.org/performance-engineered-mixtures-pem/>
- FHWA- Mobile Concrete Technology Center
<https://www.fhwa.dot.gov/pavement/concrete/trailer/index.cfm>

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