What makes durable concrete?

Celik Ozyildirim, Ph.D., P.E.
VCTIR, VDOT

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Outline

• Is concrete durable?
• What are the distresses?
• Making durable concrete depends on
  – Application (loads, environment)
  – Structural design
  – Selection of materials and proportioning
  – Construction practices
Different Concretes

Different concretes for different applications

- Low permeability
- High strength
- Self consolidating
- Durable
- Etc…
Durable Concrete

• When exposed to the environment resists
  – weathering action
  – chemical attack
  – abrasion
while maintaining the desired properties.
Pantheon

Roman concrete, 2,000 years old!
Environmental Distresses

• Freezing and thawing
• Alkali-aggregate reactions
• Sulfate attack
• Corrosion: consider both the concrete and the reinforcement (corrosion resistant reinforcement)
Freezing and Thawing Damage

Non-air entrained
ASR

Water is necessary.
Sulfate Attack

Sulfate solution penetrating.
Cracking
Drying shrinkage

Due to loss of moisture
Corrosion Related Cracking and Spalling

Chlorides penetrate through the concrete and/or the cracks
Cracking and Spalling

(chlorides on surface seep in through the leaking joints)
Durable Concrete Structures

• Require proper:
  – structural design and foundation
  – material selection and proportioning
  – construction practices
  – specifications (ERS)
Design

- Proper foundation
- Reinforcement: size, spacing, cover
- Reduced skews
- Fewer joints in decks
- Closely spaced joints in pavements
- Good drainage: Keep it dry!
Poor Foundation?
Material Selection and Proportioning

• Give proper attention to the selection of
  – cementitious material (include supplementary cementitious material)
  – water
  – aggregates
  – chemical admixtures

• low water-cementitious material ratio (0.40 to 0.45 for bridge decks)
Permeability

Coulombs

28 Days 90 Days 1 Year

Fly ash
Portland cement
Slag
Silica Fume

PC/SF/FA/S
100/0/0/0
90/5/0/0
80/0/24/0
50/0/0/50

Portland cement
Fly ash
Silica Fume
Slag
Year 1,002,012

Awesome stuff! I wish we had that on Mars.

Cast: 2,012

Build it right! Keep it dry!
Freezing and Thawing

- Proper air-voids (bubbles < 0.2 mm from any point)
- Sound aggregates
- Adequate strength
Reduced Shrinkage

• Reduced water, cement and paste contents
  – Combined aggregate (well graded) with good particle shape
  – Large maximum size aggregate
  – Admixtures: SRA, WRA

• ERS do not have minimum cementitious material requirements
CONSTRUCTION PRACTICES

- Batching
- Mixing
- Transportation
- Placement
- Consolidation
- Finishing
- Curing
Transporting - Pumping

Free fall may reduce workability and air voids
Poor Consolidation

Unacceptable voids
Consolidation and Finishing

High paste content – segregation, fine material on top
Finishing

Low slump – poor workability
Curing

Need good coverage
Curing

Keep it wet!
Curing

Avoid ponding water on the fresh surface (weakens the surface)!
Cracking
Plastic Shrinkage

Prevent evaporation!
Thermal Cracks – Bridge Deck

Differential deck/beam temperature for at least 24 hours under 22 F.
Cold weather - use external heat and insulating blankets.
Durable Concrete

Resists weathering action, chemical attack, and abrasion through

- low permeability (SCM, low w/cm)
- low water, cement, and paste content (minimal cracking)
- proper air void system
- sound aggregates
- adequate strength to resist stresses
Thank you.

Celik Ozyildirim, Ph.D., P.E.
VCTIR, VDOT