Design Options for Durability

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Bridge Division
Durability Issues

- Corrosion – Most Prominent Problem
Marine Exposure

How much chloride is in our bays?

Answer: Varies Substantially
  - Primary Factor is Freshwater Inflow
  - 10 to 30 ppt Sabine Lake Swing Bridge
  - 20 to 35 ppt Port Isabel
  - 20 to 35 ppt Matagorda Bay
  - Up to 45 ppt Nueces Bay & JFK Causeway
  - 35 ppt Ocean Water
Marine Exposure

- How much gets in the concrete?
  - Answer: *Varies Substantially*
    - Cayo Del Oso Bay (PSTRS Conc. Pile)
      - After 27 years – over 4 lbs/CY @ 1”-2”
    - Galveston Bay Causeway (CIP Cap)
      - After 65 years – Over 20 lbs/CY @ 1/4”-3/4”
      - After 44 years – Over 7 lbs/CY @ 1/4”-3/4”
    - Sabine Lake Bridge (PSTRS Beam)
      - After 49 years – 5 lbs/CY @ 0-1”
      - After 49 years – 1 lbs/CY @ 1”-2”
Deicing Chemical Use

- Question: Are the newer types of deicing chemical harmful to transportation structures?

- Answer: YES – Most of Them Are
  - MgCl₂ and CaCl₂ can lower pH and diffuse faster into concrete than NaCl
  - The general thinking is they may not be as corrosive to rebar, beware
  - CMA – Non-Corrosive – Very Expensive
  - See NCHRP 577
Durability Issues

- Corrosion – Most Prominent Problem
- Alkali-Silica Reactivity (ASR)
- Delayed Ettringite Formation (DEF)
Durability Issues

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- Sulfate Attack – Is it a Problem?
Durability Issues

- Corrosion – Most Prominent Problem
- Alkali-Silica Reactivity (ASR)
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- Sulfate Attack – Is it a Problem?
- Freeze-Thaw Damage
What Can a Designer Do?
Understanding the Spec’s

- Item 420, “Concrete Structures”
  - Mass Placements & Temperature
- Item 421, “Hydraulic Cement Concrete”
  - Allowable Mix Design Options
    - ASR/DEF
    - HPC/Sulfate Resistant Concrete
  - Air Entrainment/Freeze-Thaw
- Item 424, “Precast Concrete Structures”
  - Addresses Curing Temperatures/DEF
- Check the Special Provisions
Design Issues

- **ASR**
  - High Strengths Can Lead to ASR
  - Limit Release Strengths?
  - Item 421 Addresses – Mix Options

- **DEF**
  - High Strengths, High Temperatures, and Reactive Materials Can Result in DEF
  - Item 424 Addresses Heat Generation
  - Item 421 Addresses – Mix Options
  - Designate Mass Concrete Members
Mass Concrete

- Defined as any member with least dimension 5 feet or greater
- Heat generated during hydration can lead to cracking
- Excessive heat generation (> 160 degrees) can lead to DEF
- Submit a Plan - Needs to be Reviewed
- “Concrete Works”
- Increased maximum fly ash allowed
Design Issues

- **ASR**
  - High Strengths Can Lead to ASR
  - Limit Release Strengths?
  - Item 421 Covers - Mix Options

- **DEF**
  - High Strengths, High Temperatures, and Reactive Materials Can Result in DEF
  - Item 424 Addresses Heat Generation
  - Item 421 Covers - Mix Options
  - Designate Mass Concrete Members
  - Texas Concrete Works
ConcreteWorks Software

- **ConcreteWorks Version 1**
  - Version 1 available
    - [www.texasconcreteworks.com](http://www.texasconcreteworks.com)
    - Mass concrete temperature prediction
    - ACI 211 concrete mix design
    - It’s Free – Self Help Videos

- **ConcreteWorks Version 2**
  - Beta Release Testing
  - Service life modeling, crack risk, deck analysis, pavement analysis, precast member temperature prediction
Design Issues

- Sulfate Attack
  - Dependent on Soil
  - Examine Existing and Structures in Area (Esp. Riprap and Misc. Concrete)
  - See Sulfate Map
  - Need to Note in Plans
    - Toggle for Item 421
    - “Sulfate Resistant Concrete”
Bridge Design Guide

PROTECTIVE MEASURES AGAINST CORROSION FROM BELOW

This represents known areas of possible corrosion due to sulphate soils or salt water. There may be areas within the boundaries which are free from corrosive influence and areas outside the boundaries which are not. Careful consideration is recommended. Close proximity to salt water spray may justify the use of epoxy coated reinforcing in all parts of the structure.

Figure 3.17c
Proposed Districts/Counties Where Sulfate Resistant Concrete Required in Substructure Concrete

Structures along Red River

Past Type II Cement Requirement
New Districts with Sulfate Concern
Past Coastal and Red River Sulfate Concerns

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Sulfate Guidance

- Research is being conducted
- We need your help
- Consult with the pavement folks
- Review the Bridge Inspection Files for possible identification of sulfate attack on concrete
- Be conservative
- Test Soils – Tex-146-E, Conductivity Test for Field Detection of Sulfate
Design Issues

- Air Entrainment
  - Dependent on Environment
  - Examine Existing and Structures in Area
  - See Freeze-Thaw Map
  - Need to Note in Plans
    - Default is to include AE
    - Toggle for Item 421
    - “Air-entrainment not required for Class “C” Bent Concrete.”
Air Entrainment Specifications

“Unless otherwise shown in the plans, target an entrained air content of 4.0% for concrete pavement and 5.5% for all other concrete requiring air-entrainment. To meet the air-entraining requirements, use an approved air-entraining admixture.”
Expert Opinions

- **AASHTO – LRFD**
  - Design: Use AE if 20 or more F/T Cycles, Decks and Rails most Vulnerable

- **PCA**
  - Include AE if concrete exposed to F/T, especially if deicing chemicals are used

- **TxDOT Engineers (w/Researchers Input)**
  - HPC is F/T Resistant to a degree
  - F/T Damage Takes Time
Locations Where Air Entrainment Recommended in Structural Concrete

5.5% Target Entrained Air

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Design Issues

- Corrosion
  - Environment
    - Marine
    - Deicing Salts Used?
    - Other – Oil Field Salts, Ground Salts, …
Material Related - High Performance Concrete (HPC)

- Special Provision to 421 for HPC
  - Defaults to Mix Design Options 1-5
  - Allows Option 8 - Testing Option
Testing

- Rapid Chloride Permeability Test (RCPT)
- Ponding Tests
- Other
Material Related - High Performance Concrete (HPC)

- Special Provision to Item 421 for HPC
  - Defaults to Mix Design Options 1-5
  - Allows Option 8

- Bid Codes Cut for HPC

- Standards Modified to Account for HPC
  - Precast Piling Standard – One Sheet Now (CP)
  - PCP & PCSP (General Note to Switch to HPC)
  - Beam Standards Do Not Address HPC
    - Selectively Specify by General Note to Item 424
Districts/Counties

Where High Performance Concrete is Recommended in Structural Concrete

Limit Mix Design Options to 1 - 5

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Design Features

- **Clear Cover**
  - Decks: Where Air Entrainment is Required - Use 8 ½” Deck with 2 ½” Cover
  - Substructure: Increased Clear Cover will Help
    - AASHTO LRFD
      - Exposure to deicing salts: 2.5” to main Steel
      - Coastal: 3” to main Steel
      - Direct exposure to salt water: 4” to main Steel

- **Common Foundation Details**
  - Standard not to be used for foundations directly exposed to salt water or salt spray
Column in Marine Spray

- .45 w/c
- .4 w/c
- .45 w/c 30% FA
- .4 w/c 30% FA
- .4 w/c 5% SF

Computed by LIFE 365
Design Features

- Corrosion Resistant Reinforcing Steel
  - Epoxy Coated Steel
    - Bridge Decks – Performance has been good
      - Used in Texas for 25 years
    - Cost is negligible.
      - Black Steel $0.28/lbs, ECR $0.34/lbs
  - Use in Top and Bottom Mats
  - Continual Exposure to Moisture Can Result in Adhesion Failure
  - Dependent on Field Workers to Fix the Defects
Design Features

- Corrosion Resistant Reinforcing Steel (cont)
  - Stainless Steel?
    - 200 year design life – Maybe
    - Price $2 to $3/lbs
    - Oregon DOT
      - Stainless in Selected Members (Marine)
      - Does not mix black with stainless
      - Estimate less than 15% Additional Bridge Cost
  - Virginia DOT (Tangier Island)
    - Precast Bridge with Stainless Steel
    - $7.70/lbs (AISI Type 316LN & 2205 (Pickled))
Design Features

- Specify Corrosion Inhibiting Admixtures
  - Only Calcium Nitrite
    - Increases Chloride Threshold Level
Column in Marine Spray
Include 3 gal/CY CNI

Time to Corrosion (yrs)

Clear Cover (in)

.45 w/c
.4 w/c
.45 w/c
.4 w/c
.4 w/c
5% SF

30% FA
30% FA
30% FA

Computed by LIFE 365
Design Features

- Specify Corrosion Inhibiting Admixtures
  - Only Calcium Nitrite
    - Increases Chloride Threshold Level
  - PSTRS Concrete Seems Best Location
    - Very High Quality Concrete
    - Non-Cracked Concrete
- Case Study
  - Bridge Deck Constructed 1985
  - Included 3 gal/CY Calcium Nitrite
  - Cores Taken at Crack Location
Concrete Containing 3 gal/CY Calcium Nitrite
Concrete Containing 3 gal/CY Calcium Nitrite
Other Technologies

- Item 427, “Epoxy Paint”
  - Replaces “Epoxy Waterproofing”
    - Impermeable
    - Non UV Resistant
Epoxy Waterproofing – 22 years old
SEJ Still Functioning After 22 Years
Other Technologies

- Item 427, “Epoxy Paint”
  - Replaces “Epoxy Waterproofing”
    - Impermeable
    - Non UV Resistant

- Shrinkage Reducing Admixtures
  - Reduce Cracking

- Structural Fibers
  - Crack Control
Guidelines

- Know the Environment
- Check the Maps
- Increase Clear Cover for Durability
- Specify HPC
- Use Corrosion Resistant Rebar
  - ECR in Decks and Railing
- Air-Entrain Concrete when Needed
- Continue to Require Sulfate Resistant Concrete Based on Past Type II Usage
- Use SEJ’s When Possible
Thank You

Questions?