


DURABLE CONCRETE SOLUTIONS

ADMIXTURE AND ADDITIVE TECHNOLOGIES

MINNESOTA CONCRETE COUNCIL– JANUARY 23, 2020

1

MAKING DURABLE CONCRETE / STRUCTURES

FULL DISCLOSURE

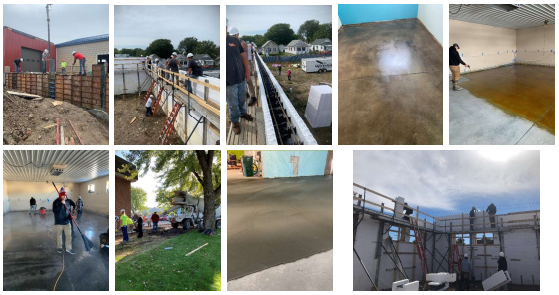
- Not a Minnesota resident
- Corporate, but not Ivory Tower
- Illinois, but not Chicago
- "Little Wisconsin"
- Northerner


2

MAKING DURABLE CONCRETE / STRUCTURES

FULL DISCLOSURE

- "Annual contributor" to the Minnesota State University System
- Investor in future Minnesota Concrete Professionals (MSU SE)



3

MAKING DURABLE CONCRETE / STRUCTURES
INTRODUCTION

PROGRAM

- ~~Earth shattering technology~~
- Durability concepts
- Brief, generate thought
- How to use the tools we have
- What's ahead?

4

MAKING DURABLE CONCRETE / STRUCTURES
DEFINING DURABILITY (ACI, PCA)

- Durability is the ability to last a long time without significant deterioration
- Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties
- Durability of concrete is determined by its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration, and will retain its original form, quality, and serviceability when exposed to its environment
- Different concretes require different degrees of durability depending on the exposure environment and properties desired
- Concrete ingredients, their proportioning, interactions between them, placing and curing practices, and the service environment determine the ultimate durability and life of the concrete

5

MAKING DURABLE CONCRETE / STRUCTURES
DEFINING DURABILITY

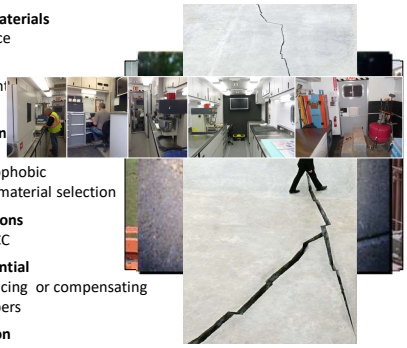
Potential consideration:

- High humidity and rain
- Ultraviolet resistance
- Moderate to severe exposure conditions for concrete
- Resistance to freezing and thawing
- Chemical resistance
- Resistance to sulfate attack
- Seawater exposure
- Chloride resistance and steel corrosion
- Resistance to alkali-silica reaction (ASR)
- Abrasion resistance
- Volume change (internal/external influences)

6

MAKING DURABLE CONCRETE / STRUCTURES
BASIC CONCEPTS

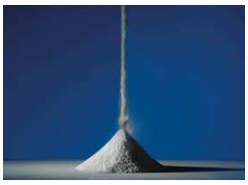
- **Starts with good materials**
  - Technical guidance
- **Increased density**
  - Low water cement
  - HRWR, PCE
- **Watertight/repellan**
  - Limit absorption
  - Crystalline, hydrophobic
  - Joint design and material selection
- **Construction solutions**
  - Consolidation, SCC
- **Limit cracking potential**
  - Shrinkage reducing or compensating admixtures, fibers
- **Corrosion protection**
  - Anodic, cathodic



7

MAKING DURABLE CONCRETE / STRUCTURES
STEP 1: IMPROVE CONCRETE DENSITY

- Use of supplementary cementitious materials such as slag, fly ash, or silica fume
- Good aggregate and sand grading
- Utilization of low water cement ratio concrete….requiring the use of a good high range water reducer

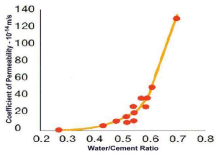


8

MAKING DURABLE CONCRETE / STRUCTURES
STEP 1: IMPROVE CONCRETE DENSITY

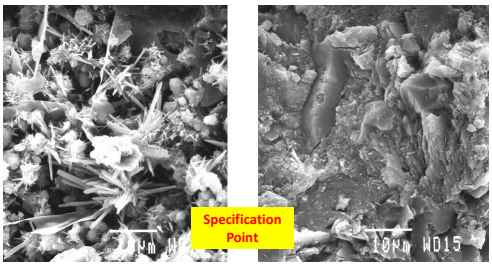
Type of pore	Size (μm)	Capillary Action
Micro Pores	< 0.1	NO
Capillary Pores	0.1 - 100	YES
Air Pores	>100	NO

- Water Reducing Admixtures
  - Use of HRWR leads to reduced w/c ratio
  - Decrease amount of free water
  - Reduced transportation of water through capillaries



9

MAKING DURABLE CONCRETE / STRUCTURES
STEP 1: IMPROVE CONCRETE DENSITY



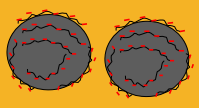
Without HRWR, W/C = 0.5 | With HRWR, W/C = 0.35

Use of water reducing admixtures reduce need for excessive amount of "convenience" water in concrete mixture resulting in reduced size of the capillaries, which are the primary source of water transportation of water through the concrete.

10

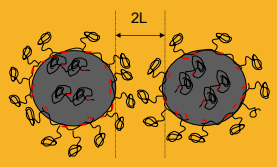
MAKING DURABLE CONCRETE / STRUCTURES
STEP 1: IMPROVE CONCRETE DENSITY

Conventional Water Reducer



Electrostatic Repulsion

Polycarboxylate Water Reducer



Electrostatic Repulsion and Steric Hindrance

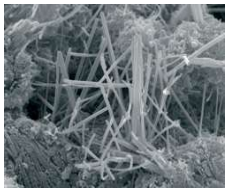
- 15% → 40%water reduction
- Longer life
- Slump control
- Air stability
- Greater production efficiency

11

MAKING DURABLE CONCRETE / STRUCTURES
STEP 2: REDUCE CONCRETE PERMEABILITY

Crystalline

- In the presence of water, the ingredients of these products react to form non-soluble crystals that fill and plug the pores and micro cracks in concrete.



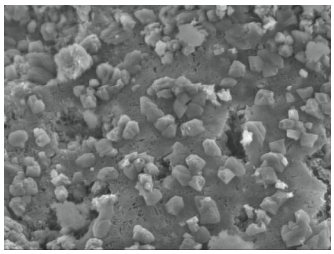
Hydrophobic

- Integral PRA products which work by developing polymer barriers inside pores during the hydration process. The surface tension of the water itself keeps it from being able to penetrate the concrete

12

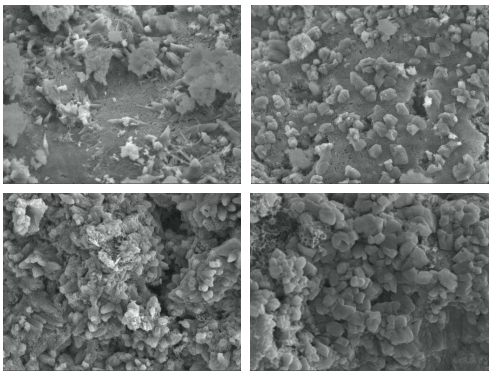
MAKING DURABLE CONCRETE / STRUCTURES
CRYSTALLINE PERMEABILITY REDUCING ADMIXTURES

- Treated mortar sample view at a fracture plane using SEM: A multitude of angular calcite crystals are observed at relatively low magnification. Such crystals can be found all over the fracture surface.
- Crystal growth typically starts within 3-4 days after contact with water.



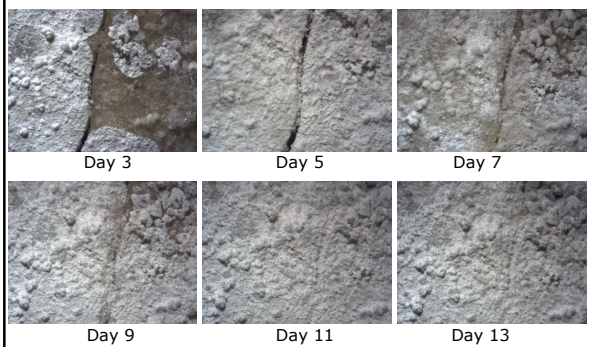
13

MAKING DURABLE CONCRETE / STRUCTURES
CRYSTALLINE GROWTH OVER TIME (1 WEEK INTERVALS)



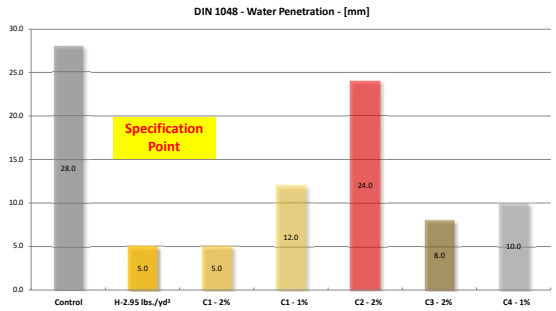
14

MAKING DURABLECONCRETE / STRUCTURES
CRACK HEALING – 13 DAYS MONITORING



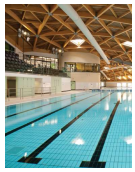
15

MAKING DURABLECONCRETE / STRUCTURES
CRYSTALLINE ADMIXTURES – RELATIVE PERFORMANCE



16

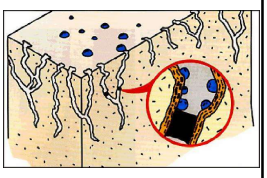
MAKING DURABLECONCRETE / STRUCTURES
CRYSTALLINE PERMEABILITY REDUCING ADMIXTURES




17

MAKING DURABLE CONCRETE / STRUCTURES
HYDROPHOBIC PERMEABILITY REDUCING ADMIXTURES

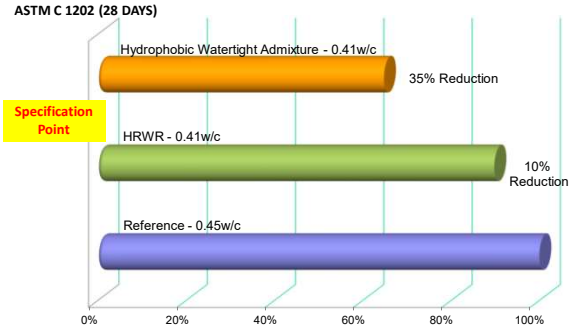
- PRA admixture reduces water attraction of the substrate and reduces capillary forces of the concrete
- Admixture reacts to form insoluble and hydrophobic calcium stearate, which deposits on the walls of the pores and ultimately blocks the pores
- Hydrophobic capillary coating results in decreased rate of water permeability and water absorption through concrete




18

MAKING DURABLE CONCRETE / STRUCTURES
HYDROPHOBIC PERMEABILITY REDUCING ADMIXTURES

RAPID CHLORIDE PERMEABILITY TEST
ASTM C 1202 (28 DAYS)



19

MAKING DURABLE CONCRETE / STRUCTURES
HYDROPHOBIC PERMEABILITY REDUCING ADMIXTURES

Lincoln Memorial Reflecting Pool
Washington, DC
- 6.75M gallons
- Leaking, used 30M gallons annually
- Hydrophobic PRA

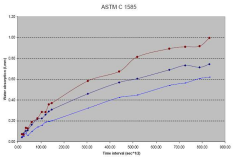


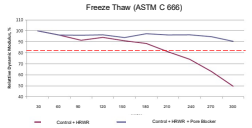

20

MAKING DURABLE CONCRETE / STRUCTURES
INTEGRAL PERMEABILITY REDUCING ADMIXTURES

EFFECT OF PORE BLOCKING WATERTIGHT CONCRETE ADMIXTURES ON OTHER CONCRETE PROPERTIES

- Prevents water and other potentially harmful compounds such as chlorides to enter structure
- No negative affect on compressive strength
- Does not effect slump retention
- No negative effect on air void quality
- Improves freeze thaw durability





21

MAKING DURABLE CONCRETE / STRUCTURES
INTEGRAL WATER REPELLANTS

Exterior concrete mix with an integral water repellant for durable, freeze-thaw resistant applications

Advantages
- Water repellant concrete
- Reduced water and chloride penetration
- Improved freeze-thaw durability and de-icing resistance
- Efflorescence reduction (immediate)
- Better appearance (uniformity, color vibrancy)
- Extended service life vs. untreated concrete
- Faster production rates vs. sealing

Applications
- Exterior slabs
- Driveways
- Commercial
- Residential

22

MAKING DURABLE CONCRETE / STRUCTURES
INTEGRAL WATER REPELLANTS

Built in water repellency
- Integral within the concrete

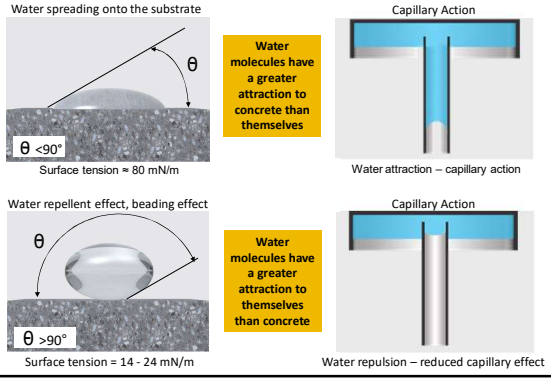
Contractor TIME and COST savings
- Alternative to sealer application
- Material, mobilization, labor, equipment, and waste savings
- Faster start to finish projects (no second trips)
- No VOC's for contractor or environment

Uniform appearance
- Customer satisfaction
- No splotchy or peeling sealer effect
- Improved color vibrancy and stability

Value added concrete to owners
- Improved durability and service life

23

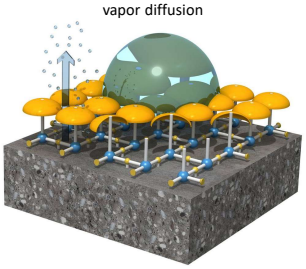
MAKING DURABLE CONCRETE / STRUCTURES
INTEGRAL WATER REPELLANTS



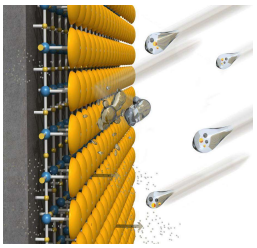
24

MAKING DURABLE CONCRETE / STRUCTURES
INTEGRAL WATER REPELLANTS

Breathable for water vapor diffusion



Integrally bonded within substrate



Umbrella effect

25

26

MAKING DURABLE CONCRETE / STRUCTURES
INTEGRAL WATER REPELLANTS

27

MAKING DURABLE CONCRETE / STRUCTURES
INTEGRAL WATER REPELLANTS

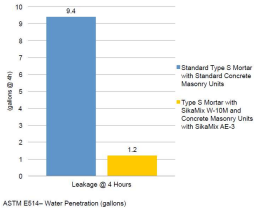
28

MAKING DURABLE CONCRETE / STRUCTURES
INTEGRAL WATER REPELLANTS

ASTM C672
- Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals

ASTM C666
- Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing

ASTM E514
- Standard Test Method for Water Penetration and Leakage Through Masonry

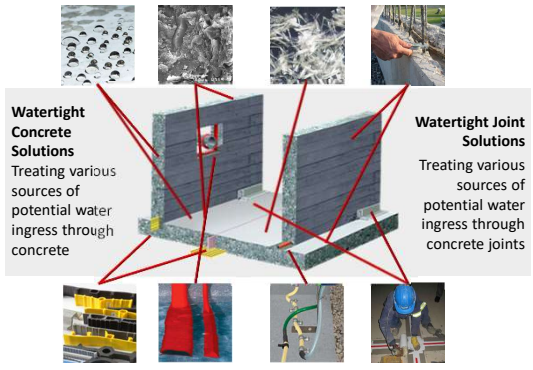


Reduction In Water Penetration: 87.2%

Specification Point

29

MAKING DURABLE CONCRETE / STRUCTURES
WATERTIGHT SOLUTIONS



Watertight Concrete Solutions
Treating various sources of potential water ingress through concrete

Watertight Joint Solutions
Treating various sources of potential water ingress through concrete joints

30

MAKING DURABLE CONCRETE / STRUCTURES
STEP 3: FILLING ALL OF THE VOIDS - SCC

A new solution to an old problem…

31

MAKING DURABLE CONCRETE / STRUCTURES
SCC – THE DIFFERENCE

32

MAKING DURABLE CONCRETE / STRUCTURES
STEP 3: FILLING ALL OF THE VOIDS - SCC

What is SCC?

- Self consolidating concrete (SCC) is highly flowable, non segregating concrete that can spread into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation (ACI 237)

33

MAKING DURABLE CONCRETE / STRUCTURES
SCC APPLICATION

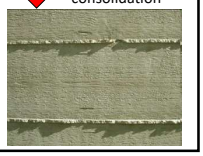
34

MAKING DURABLE CONCRETE / STRUCTURES
STEP 3: FILLING ALL OF THE VOIDS - SCC

- Improper placement of concrete can have the ultimate impact on watertightness of entire structure
  - Heavily reinforced and congested areas with limited access can be of greatest concern
- Proper placement and consolidation is an absolute must in cases when watertight concrete is used
- To provide maximum watertightness, SCC is an ideal tool

Improper consolidation

Proper consolidation



35

MAKING DURABLE CONCRETE / STRUCTURES
SUPERPLASTICIZED VS. SCC

Superplasticized

- Measured by slump
  - 6" to 10-1/2"
- Cohesive and non-segregating
- Requires vibration for proper consolidation during placement

Self Consolidating

- Measured by spread
  - 20" to 30"
- Cohesive and non-segregating
- Requires no vibration during placement

Specification Point



36

MAKING DURABLE CONCRETE / STRUCTURES
SELF CONSOLIDATING CONCRETE

Key Advantages:

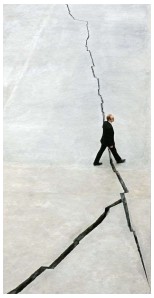
- Significant noise reduction: little or no vibration required
- Improved Health and Safety
- Economics:
  - Reduced manpower requirements (faster and easier placement)
  - Less wear & tear and maintenance for equipment (cranes, mixers, vibrators, etc.)
  - Less patching and repair
- Consistency
- New design possibilities:
  - Possibility of casting heavily reinforced, inaccessible and complicated shapes

FILLS ALL THE VOIDS!

37

MAKING DURABLE CONCRETE / STRUCTURES
STEP 4: LIMIT / PREVENT CRACKING

- Utilization of low water cement ratio mix (limit paste fraction)
- Utilize largest possible max size coarse aggregate (but also keep concrete workable)
- Cure the concrete by controlling temperature and moisture movement
- Utilize a shrinkage reducing and/or compensating admixture
- Use of fibers



38

MAKING DURABLE CONCRETE / STRUCTURES
STEP 4: LIMIT / PREVENT CRACKING

Drying Shrinkage:

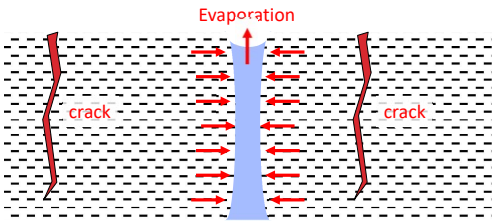
- Loss of moisture from hardened concrete surface
- Volume of concrete reduces and it shrinks
- Water in capillary exerts forces on capillary wall

SRA/SCA (shrinkage reducing/ compensating admixtures):

- Utilized in any concrete and mortar applications where reduced shrinkage is required
- Reduces curling
- Improves aesthetics, watertightness and durability

39

MAKING DURABLE CONCRETE / STRUCTURES
SHRINKAGE REDUCING ADMIXTURES



How SRA's work:

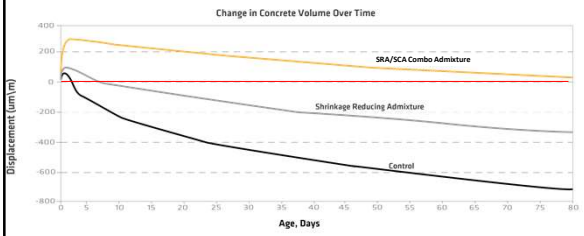
- Reduces surface tension of the liquid
- Forces on the wall are reduced

Advantages:

- Up to 40% reduction in shrinkage

40

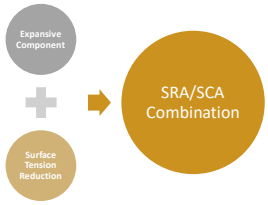
MAKING DURABLE CONCRETE / STRUCTURES
SHRINKAGE CONTROLLING DESIGN



41

MAKING DURABLE CONCRETE / STRUCTURES
SHRINKAGE CONTROLLING ADMIXTURES

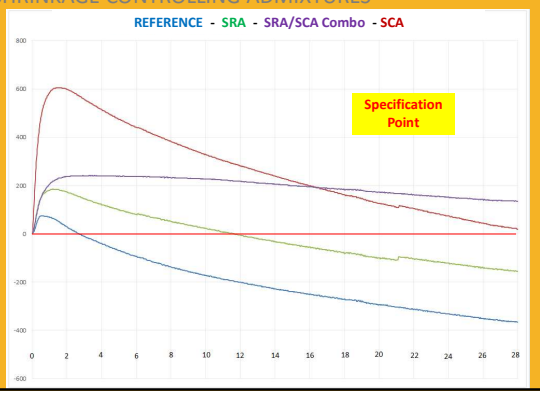
- $MgO + H2O = Mg(OH)_2$ (magnesium hydroxide)
- Expansive effect – compensates for the shrinkage of Portland Cement
- Expansion is very predictable
- When "lightly burnt", rate of expansion closely matches PC rate of shrinkage
- Very stable material – only likes water



42

MAKING DURABLE CONCRETE / STRUCTURES

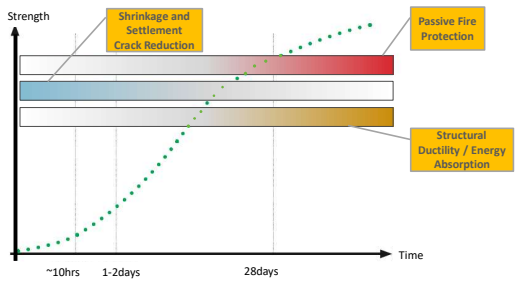
SHRINKAGE CONTROLLING ADMIXTURES



43

MAKING DURABLE CONCRETE / STRUCTURES

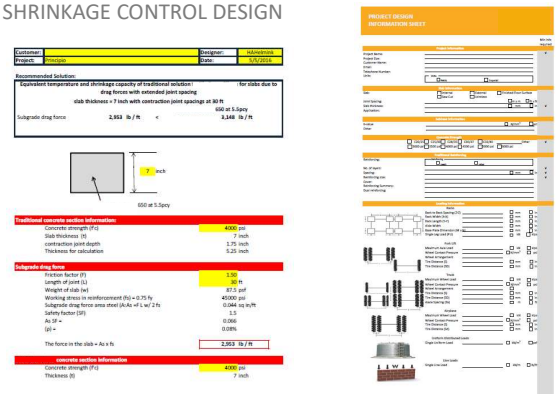
SHRINKAGE CONTROL WITH FIBERS



44

MAKING DURABLE CONCRETE / STRUCTURES

SHRINKAGE CONTROL DESIGN



45

MAKING DURABLE CONCRETE / STRUCTURES
SHRINKAGE CONTROLLING ADMIXTURES

Benefits
- Reduced cracking potential due to drying and autogenous shrinkage
- Reduced curling
- Increased joint spacing
- Substantially improved impermeability
- Improved concrete durability

46

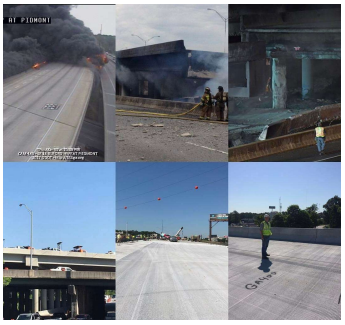
MAKING DURABLE CONCRETE / STRUCTURES
SHRINKAGE CONTROLLING EXAMPLE

University of Utah Basketball Court
- 4 pcy macro fibers, 5% SRA/SCA
- 14,000 sq. ft. jointless
- Met FF and FL requirements

47

MAKING DURABLE CONCRETE / STRUCTURES
SHRINKAGE CONTROLLING EXAMPLE

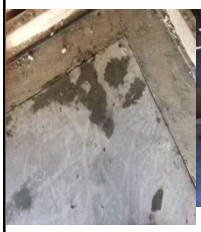
I-85 Bridge Deck Replacement
Atlanta, Georgia
- Accelerated mix design
- SRA/SCA design
- 3 day vs. 7 day wet cure
- NO cracking



48

MAKING DURABLE CONCRETE / STRUCTURES
SHRINKAGE CONTROLLING EXAMPLE

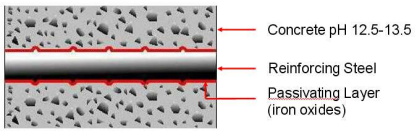
Virginia Tipping Slab
- 65' x 95' slab
- 60 lbs. steel fiber
- 5% SRA/SCA
- No joints, no cracks



49

MAKING DURABLE CONCRETE / STRUCTURES
STEP 5: CORROSION INHIBITION

Alkaline environment protects reinforcing steel from corrosion



Conditions for Corrosion
- Breakdown of the passivating layer (carbonation, chlorides, sulfates)
- Electrolyte (continuous pore water)
- Oxygen (concrete pores)

50

MAKING DURABLE CONCRETE / STRUCTURES
STEPS TO MINIMIZE CORROSION

- Adequate concrete cover
- Concrete quality (low permeability, no cracks)
- Epoxy coated rebar
- Stainless steel reinforcement
- Cathodic protection
- Protective coatings
- Corrosion inhibitors


51

MAKING DURABLE CONCRETE / STRUCTURES
CALCIUM NITRITE TECHNOLOGY

Anodic Corrosion Inhibitor

- Oxidizes the steel to form ferric oxide, which resists chloride attack
- Proven technology
- Track record
- Excellent corrosion protection
- ASTM C-494 Type C (Accelerating)
- Typical dosage of 1 gal/CY – 6 gal/CY
- **"CNI" Admixtures**

Specification Point

52

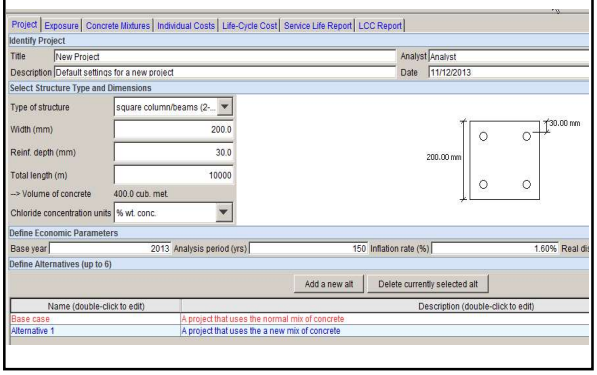
MAKING DURABLE CONCRETE / STRUCTURES
AMINO ALCOHOL TECHNOLOGY

- Multi-functional inhibitors (some)
  - Anodic/cathodic protection
  - Migrating inhibitor – Penetrates through the concrete to the steel reinforcement and gets absorbed on the surface
  - Displaces chloride ions from steel surface and forms a continuous film
- Selected blend of organic (amino alcohols) and inorganic inhibitors
- No negative effects of concrete properties:
  - Slump
  - Air
  - Set time
  - Finishability

Specification Point

53

MAKING DURABLE CONCRETE / STRUCTURES
CORROSION PROTECTION DESIGN



54

MAKING DURABLE CONCRETE / STRUCTURES

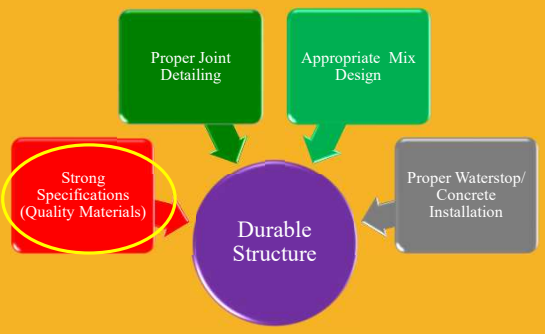
Five basic concrete properties addressed

1. Density – water reducing admixtures
   - High range – PCE based
2. Watertightness, absorption, permeability – waterproofing or repelling admixtures
   - Hydrophobic pore blocking , crystalline pore filling
   - High quality jointing material
3. Reduce voids/ensure consolidation
   - SCC
4. Limit or control crack potential
   - Shrinkage reducing and controlling admixtures
   - Fiber reinforcement
5. Corrosion protection - inhibitors
   - Anodic
   - Cathodic

Increasing concrete durability / quality

55

MAKING DURABLE CONCRETE / STRUCTURES
KEYS TO SUCCESS



56

MAKING DURABLE CONCRETE / STRUCTURES
SOLUTIONS IN STRONG SPECIFICATIONS

If you don't specify it, you probably won't get it!

It's not enough to specify it, define what you want it to do.

Specification Point

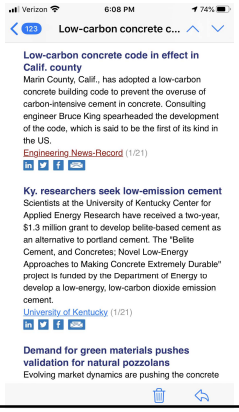
57

MAKING DURABLE CONCRETE / STRUCTURES
WHAT IS ON THE HORIZON?

Specialty Admixtures
- Performance, solutions, efficiency
- Adaptability
  - Resources – sands, aggregates, cements, supplementals

Environmental pressure
- Processes, regulatory
- Producer availability
  - Resources
  - Blended cements
- Manufacturer availability
  - Raw materials

Technology
- Placed performance
- Quality control
- Productivity



58

BRINGING IT ALL TOGETHER...

THANK YOU FOR YOUR ATTENTION

59