What is Concrete?

- Economical with a long life & low maintenance
- 2nd most common man-made material
- 1st in rank: potable water
- Concrete does not rot, corrode, or decay.
- Concrete can be molded or cast into almost any desired shape.
- Concrete is fire-safe & able withstand high temperatures.
- Concrete is resistant to wind, water, rodents, and insects.
- 12 BILLION cu meters per year globally
- ~1 cu yd / person / year in USA
- More than 70 Billion cubic meters placed in USA since 1930
  - ~10 Billion cu meters > 20 years old

How does concrete fail?

- Concrete has (compared to other building materials)
  - low tensile strength (~10% of compressive strength)
  - Solution: add reinforcement such as rebar, fibers, FRP
  - low ductility (it’s brittle)
  - low strength-to-weight ratio (it's heavy)
  - responds to environment (it changes with time)
  - Alkalinity drops, strength increase
  - has permeability (ingress of deleterious materials)
    - water/air/moisture migration
  - is susceptible to chemical attacks (acids, Alkaline Aggregate Reaction aka AAR, etc...)
  - it cracks (most common failure mode)
  - Steel corrodes
    - Chloride, carbonation, and polarization interaction
    - Rust expands, causing cracking, spalling, and eventual failure

ALL of these properties change as the concrete ages.
Abstract

- Concrete structures can be subjected to physical or chemical attacks by various substances, including water, acids, alkalis, salt solutions, and organic chemicals.
- Damage may vary in intensity from surface discoloration or roughening to catastrophic loss of structural integrity due to acid attack or reinforcing steel corrosion.
- In 2013 ACI 515 published their “Guide to Selecting Protective Treatments for Concrete”
- This document
  - Compares the extent of chemical attack for > 300 chemicals on concrete
  - Suggests possible preventative surface treatments to minimize these effects.
- Many of the conditions effecting the installation of coatings on concrete such as concrete condition assessment, surface preparation, and service conditions will be forthcoming in future documents.
ACI 515.2R-13: Guide to Selecting Protective Treatments for Concrete

• CHAPTER 1—INTRODUCTION AND SCOPE
• CHAPTER 2—NOTATION AND DEFINITIONS
• CHAPTER 3—TABLES OF CHEMICALS, THEIR EFFECTS ON CONCRETE, AND PROTECTIVE TREATMENTS
  – 3.1—Aggressive substances
  – 3.2—Treatment methods
• CHAPTER 4—PROTECTIVE TREATMENTS AND SYSTEMS DESCRIPTIONS
• CHAPTER 5—REFERENCES

3.1—Aggressive substances

• Table 3.1a—Acids
• Table 3.1b—Salts and alkalies
• Table 3.1c—Petroleum oils
• Table 3.1d—Coal-tar distillates
• Table 3.1e—Solvents and alcohols
• Table 3.1f—Vegetable oils
• Table 3.1g—Fats and fatty acids (animal)
• Table 3.1h—Miscellaneous substances
  Alum ➔ Zinc Slag

Notes

Special notation characters are referenced in Tables 3.1a through 3.1h to provide further clarification of specific chemicals and are shown as letters in the column headed “Notes.”

- a = sometimes used in food processing or as food or beverage ingredient; ask for advisory opinion of Food and Drug Administration (FDA) regarding coatings for use with food ingredients.
- b = water with a pH higher than 6.5 may be aggressive if it also contains bicarbonate; natural water is usually of pH higher than 7.0 and seldom lower than 6.0, though pH values as low as 0.4 have been reported (Nordstrom et al. 2000); for pH values below 3, protect as for dilute acid.
- c = frequently used as a deicer for concrete pavements; if the concrete contains too little entrained air, a pour-quality air-void system, or has not been aged more than 1 month, repeated application may cause surface scaling; for protection under these conditions, refer to decising salt.
- d = carbon dioxide dissolves in natural waters to form carbonic acid solutions, when it dissolves to an extent of 0.9 to 3 ppm, it is destructive to concrete.
- e = frequently used as deicer for airplanes; heavy spillage on runway pavements containing too little entrained air may cause surface scaling.
- f = in addition to the intentional fermentation of many raw materials, much unwanted fermentation occurs in the spoilage of foods and food wastes, also producing lactic acid.
- g = contains carbonic acid, fish oils, hydrogen sulfide, methyl amine, brine, and other potentially reactive substances.
- h = water used for cleaning coal gas; compositionally, coal-washing gas can contain gases based on hydrogen sulfide, ammonia, carbon dioxide, and carbon monoxide (Kohl and Neilson 1997); the reported pH can range from as low as 1.7 to as high as 8.5.
- j = in those limited areas of the United States where concrete is made with reactive aggregates, reactive aggregate reaction products can cause disruptive expansion.
Notes

K = composed mostly of nitrogen, oxygen, carbon dioxide, carbon monoxide, and water vapor; also contains unburned hydrocarbons, partially burned hydrocarbons, oxides of nitrogen, and oxides of sulfur. Nitrogen dioxide and oxygen in sunlight may produce ozone, which reacts with some of the organics to produce formaldehyde, percarbonylates, and other products.

I = contains chromium trioxide and a small amount of sulfate or nearly saturated ammonium chromic sulfate, and sodium sulfate.

M = many types of solutions are used, including (a) sulfate—contains copper sulfate and sulfuric acid (b) cyanide—contains copper and sodium cyanides and sodium carbonate (c) rochelle—contains these cyanides, sodium carbonate, and potassium sodium tartrate (d) others such as fluoroborate, pyrophosphate, amine, or potassium cyanide

N = contains lead fluorocides and fluoroclastic acid.

P = reference to combustion of coal, which produces carbon dioxide, water vapor, nitrogen, hydrogen, carbon monoxide, carbohydrates, ammonia, nitric acid, sulfur dioxide, hydrogen sulfide, soot, and ashes.

Q = molten paraffin absorbed by porous concrete that is subsequently immersed in water can cause concrete disintegration from sorptive forces.

F = contains nickelous chloride, nickelous sulfate, boric acid, and ammonium ion.

S = may contain various mixtures of blood, fats and oils, bile and other digestive juices, partially digested vegetable matter, urine, and manure, with varying amounts of water.

V = usually contains zinc sulfate in sulfuric acid; sulfuric acid concentration may be low—approximately 6 mass percent in low current density process—or higher, approximately 22 to 38 mass percent in high current density process.

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### Aggressive Substances + Protective Treatments ≠ Solution

#### CHAPTER 4—PROTECTIVE TREATMENTS AND SYSTEMS DESCRIPTIONS

- 4.1—Magnesium fluorocarbonate or zinc fluorocarbonate
- 4.2—Alkali silicates, sodium silicate, (water glass), potassium silicate, lithium silicate
- 4.3—Drying oils
- 4.4—Coumarone-indene resin
- 4.5—Styrene-butadiene (SBR) copolymer resin
- 4.6—Chlorinated rubber
- 4.7—Chlorosulfonated polyethylene (hypalon)
- 4.8—Vinyl and latex-based materials
- 4.9—Bituminous paints, mastics, and enamels
- 4.10—Polyester and vinyl ester materials
- 4.11—Polyethylene/nylon
- 4.12—Epoxies
- 4.13—Neoprene
- 4.14—Polyurethane
- 4.15—Coal tar and coal tar epoxies
- 4.16—Chemical-resistant masonry units, mortars, grouts, and concretes
- 4.17—Sheep rubber
- 4.18—Resin sheets
- 4.19—Lead sheets
- 4.20—Glass
- 4.21—Acrylics, methyl methacrylate (PMMA), and high molecular weight methacrylate (HMWM)
- 4.22—Silane, silazane, and siloxanes (organosilicon compounds)
- 4.23—Metalizing
- 4.24—Crystalline coatings and admixtures
- 4.25—Polyurea
- 4.26—Adjoint additives
**Increased Cover**

**PROs**
- Coatings bridge cracks
- Additional protection
- Slow downs carbonation process
- Renewable
- Inexpensive
- Possible to Enhance Appearance
  - Texture?
  - Self-cleaning?

**CONs**
- Consumable (coatings)
- Section thickness increase (cover)
- Load increase (reparis)
- Defects may magnify issues
- Detail and Inspection Intensive

**Repair mortars, Concrete Anti-carbonation coatings**

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**Penetrating Sealers**

**PROs**
- Renewable
- Inexpensive
- No Appearance
- Easy to apply
- Hydrophobization

**CONs**
- Consumable
- Maintenance
- Effectiveness Monitoring
- High Hydrostatic
- Crack Bridging
- Solvent?
- Overspray

**Silane Siloxane Siliconate Others**

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**Surface Applied Corrosion Inhibitor**

**PROs**
- Renewable
- Inexpensive
- No Appearance
- Easy to apply

**CONs**
- Inhibition, not solving
- Effectiveness monitoring
- Penetration
- Residue
- Volatility
- Various technologies available
- Life cycle
- Product compatibility
- Opportunities for new technologies

**Amino alcohol**
**Amino carboxylate**
**Silicate**
**Aminofunctional silanes**
**Nitrites**

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**Traffic Membranes**

**PROs**
- Aesthetic Appearance
- Relatively Inexpensive
- Recoatable & Repairable

**CONs**
- May Need Dry Substrate
- Surface Preparation
- Maintenance
- Abrasion & CTE
- Snow Removal
- Impermeable Trap Moisture

**Breathable Impermeable Resins systems**

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Systems Selection

**Surface Constraints**
- Concrete Quality
  - Age
  - Finish
  - Porosity
  - Cracking
  - Strength

**Application Constraints**
- Site Conditions
  - Utilities
  - Job planning
  - Specifications

**Service Conditions**
- Factors
  - Duration
  - Mechanical factors
  - Thermal factors

**Treatment Options**
- Surface preparation
  - Pressure wash
  - Equipment
  - Surface retarders

**Owner Expectations**
- Specifications
- Owners
- Design firms
- Financial ($)
- Return on investment
- Budget Envelope
- Structures
- Recent
- Old
- Historical value

**Surface Preparation Methods Achieve Different Profile Ranges**

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Ref: Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays - Guideline No. 03732
SELECTING PROTECTIVE CONCRETE TREATMENTS IS AN INFORMED COMPROMISE.

Special thanks Fred Goodwin, Fellow Scientist BASF Construction Chemicals

If you have any questions about this presentation, please feel free to leave your business card or visit us at Booth #