INTERNATIONAL CONCRETE REPAIR INSTITUTE

MASTER® BUILDERS SOLUTIONS

ICRI Montreal
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Protective Coatings for Infrastructures
Inspired by ACI 515.2R-13
Guide to Selecting Protective Treatments for Concrete

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BASF We create chemistry

- Background
- Aggressive Substances
- Protective Systems and Treatments
- The Tables
- Notation
- Next Steps

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.

What would it cost ($) to restore our infrastructure?

http://www.infrastructurereportcard.org/report-cards

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

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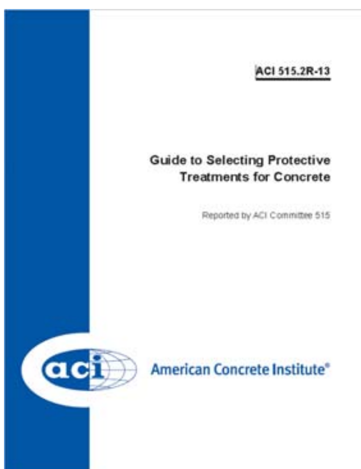

1936
Committee Founded (one of the older committees)

1966
Published "Guide for the Protection of Concrete Against Chemical Attack by Means of Coatings and Other Corrosion Resistant Materials"

1979
Published "A Guide to the Use of Waterproofing, Dampproofing, Protective, and Decorative Barrier Systems for Concrete" 1985-

1986
Revised and Published 515.1R-79 (revised 1985) in MCP

1998, 2001, 2005, 2008
Revisions not approved.

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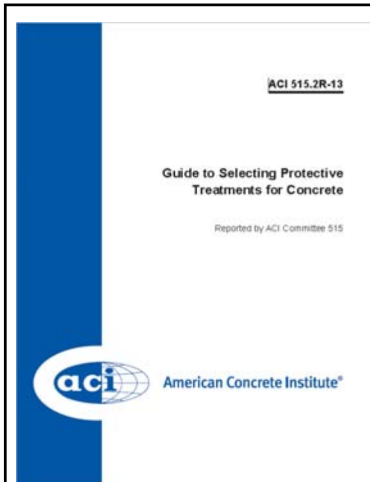

2007
PCA IS001 "Effects of Substances on Concrete and Guide to Protective Treatments", Beatrix Kerkhoff
Restructured committee tasks, "*borrowed*" from Portland Cement Association (CA) IS001 for "the missing link"

2013
Published ACI 515.2R-13 "Guide to Selecting Protective Treatments for Concrete"

2013
Began development of additional documents
515.AR: Guideline for Dialog Between the Specifier and the Owner for Protective Systems for Concrete
515.ZR: Assessment, Surface Preparation, and Application Guide for Protective Systems for Concrete (Draft balloted)

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ACI 515.2R-13: Guide to Selecting Protective Treatments for Concrete

3.1—Aggressive substances

- Table 3.1a—Acids
- Table 3.1b—Salts and alkalis
- 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 → **Z**inc 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 bicarbonates; 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 poor-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 deicing salts.

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 spoiling 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 Neilsen 1997); the reported pH can range from as low as 5.7 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, peracylnitrates, and other products.

l = 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 fluoborate, pyrophosphate, amine, or potassium cyanide

n = contains lead fluosilicates and fluosilicic 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.

r = 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 28 mass percent in high current density process.

Substance	Notes	Effect on Concrete	Protective Treatments
Acetate, calcium	c	Slow disintegration	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16 (II, III, V, VI, VII, VIII), 17, 24, 25
Acetate, sodium	c	None	
Chloride, calcium† Chloride, potassium Chloride, sodium* Chloride, strontium	a, c a, c a, c a, c	None, unless concrete is alternately wet and dry with the solution. Concentrated CaCl2 solutions, however, disintegrate concrete, whereas weak solutions do not. In porous or cracked concrete, attacks steel. Steel corrosion could cause concrete to spall (Concrete Construction Problem Clinic 1976; Portland Cement Association 2012	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16 (II, III, V, VI, VII, VIII), 17, 21, 24, 25
Ashes, cold	c	Harmful if wet, when sulfides and sulfates leach out. Refer to "Sulfate, sodium," under Table 3.1b—Salts and alkalis.	1, 2, 3, 8, 9, 10, 13, 16 (II, III, V), 24, 25
Ashes, hot	c	Thermal expansion	16 (calcium aluminate cement, fire-clay, and refractorysilicate-clay mortars)
Deicers and anti-icers	c	Chlorides (calcium, magnesium, and sodium) and non-chlorides (calcium magnesium acetate, potassium and sodium acetates and formates, urea, and ethyl alcohol) cause scaling of concrete. Air-entrained concrete does not need added protection from deicers. Potassium acetate deicers or anti-icers and, to a lesser extent, potassium formate and sodium acetate or formate could accelerate alkali-silica reaction when reactive aggregates are present (Rangaraju et al. 2005).	50 mass percent solution of boiled linseed oil in kerosene, soybean oil, modified castor oil, cottonseed oil, sand-filled epoxy, coal-tar epoxy, 21,* 22

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Aggressive Substances
+
Protective Treatments
≠
Solution

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CHAPTER 4—PROTECTIVE TREATMENTS AND SYSTEMS DESCRIPTIONS

- 4.1—Magnesium fluosilicate or zinc fluosilicate
- 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—Vinyls and latex-based materials
- 4.9—Bituminous paints, mastics, and enamels
- 4.10—Polyester and vinyl ester materials
- 4.11—Polyurethane/urethane
- 4.12—Epoxy
- 4.13—Neoprene
- 4.14—Polysulfide
- 4.15—Coal tar and coal-tar epoxy
- 4.16—Chemical-resistant masonry units, mortars, grouts, and concretes
- 4.17—Sheet rubber
- 4.18—Resin sheets
- 4.19—Lead sheet
- 4.20—Glass
- 4.21—Acrylics, methyl methacrylate (MMA), and high molecular-weight methacrylate (HMWM)
- 4.22—Silane, siloxane, and siliconates (organosilicon compounds)
- 4.23—Metalizing
- 4.24—Crystalline coatings and admixtures
- 4.25—Polyurea
- 4.26—Adjunct additives

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Increased Cover

→ Repair mortars, Concrete
Anti-carbonation coatings

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

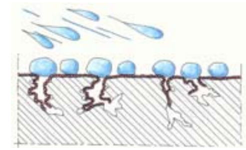
CONs
- Consumable (coatings)
- Section thickness increase (cover)
- Load increase (repairs)
- Defects may magnify issues
- Detail and Inspection Intensive

Penetrating Sealers

→ Silane
Siloxane
Siliconate
Others

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

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

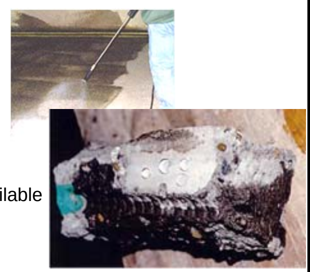


Surface Applied Corrosion Inhibitor

→ Amino alcohol
Amino carboxylate
Silicate
Aminofunctional silanes
Nitrites

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



Traffic Membranes

→ Breathable
Impermeable
Resins systems

PROs
- Aethestic Appearance
- Relatively Inexpensive
- Recoatable & Repairable

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

Reinforcement coatings

Epoxy
Cement/Epoxy Hybrid
Cement/Latex
Zinc-based

PROs

- Field application
- Low cost
- Mature technology
- Some claim bonding agents

CONs

- Pinholes & Under-bar
- Bond to Concrete Window?
- Continuity of Coating
- Hardening Depending on Environment
- Incipient Anode

Systems Selection

Surface Constraints

Concrete Quality
- Age
- Finish
- Porosity
- Cracking
- Strength

Exposure before Installation
- Duration
- Mechanical Factors
- Thermal factors
- Contamination

Orientation
- Horizontal /Vertical, Sloped
- Slab-on grade, Elevated

Application Constraints

Site Conditions
- Utilities
- Job planning
- Specifications
- Regulations

Exposure during Installation
- Environmental factors
- Application method
- Applicator skills
- Return to service

Service Conditions

Factors
- Duration
- Mechanical factors
- Thermal factors
- Others…

Exposure
- Continous
- Cyclical
- Primary or Secondary
- Abrasion/Erosion
- Friction

Treatment Options

Surface preparation
- Pressure wash
- Equipment
- Surface retarders
- Etc…

Substrate
- Wet
- Dry
- Damp

Owner Expectations

Specifications
Owners
Design firms

Financial ($)
Return on Investment
Budget Envelope

Structures
Recent
Old
Historical value

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Surface Preparation Methods Achieve Different Profile Ranges

Material to be applied	Concrete Surface Profile CSP 1	CSP 2	CSP 3	CSP 4	CSP 5	CSP 6	CSP 7	CSP 8	CSP 9	CSP 10
Sealers, 0 to 3 mils (0 to 0.075 mm)	■	■								
Thin films, 4 to 10 mils (0.01 to 0.025 mm)	■	■	■							
High-build coatings, 10 to 40 mils (0.025 to 1.0 mm)			■	■	■					
Self-leveling toppings, 50 mils to 1/8 in. (1.2 to 3 mm)				■	■	■				
Polymer overlays, 1/8 to 1/4 in. (3 to 6 mm)					■	■	■	■	■	
Concrete overlays and repair materials, >1/4 in. (>6 mm)					■	■	■	■	■	■

Ref. Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays - **Guideline No. 03732**

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Surface Preparation Methods Achieve Different Profile Ranges

Surface preparation method	Concrete Surface Profile CSP 1	CSP 2	CSP 3	CSP 4	CSP 5	CSP 6	CSP 7	CSP 8	CSP 9	CSP 10
Detergent scrubbing	■									
Low-pressure water cleaning	■									
Grinding	■	■								
Acid etching	■	■	■							
Needle scaling		■	■	■						
Abrasive blasting		■	■	■	■	■	■			
Shotblasting		■	■	■	■	■	■	■	■	
High- and ultra-high-pressure water jetting			■	■	■	■	■	■	■	■
Scarifying				■	■	■	■			
Surface retarder (1)					■	■	■	■	■	■
Rotomilling						■	■	■	■	
Scabbling							■	■	■	
Handheld concrete breaker							■	■	■	■

(1) Only suitable for freshly placed cementitious materials

Ref. Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays - **Guideline No. 03732**

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SELECTING PROTECTIVE CONCRETE TREATMENTS

IS

AN INFORMED COMPROMISE

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Special thanks
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