A Study of Microbiological Induced Corrosion

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Introduction

• The Process of MIC
• The Purdue Study
• Next Steps
• Current Precautions
• Summary
About NPCA

• International trade association
• Established in 1965
• Dedicated to expanding the use of quality concrete products
About NPCA

- The Precast Show
- Educational seminars
- Industry publications
- Technical service
- Quality Control Program
- Committees
Industry Outreach

- National
- Regional
Corrosion
Thiobacillus
Common Myths

• The bacteria eats concrete
• The $\text{H}_2\text{S}$ gas corrodes the concrete
• MIC is rampant
MIC Attributes

- Bacteria / Biofilm
- Low dissolved oxygen in wastewater
- Sulfates in the effluent
- Turbulence
- Moisture on the walls above water line
- Reactive compounds in concrete
- Low effluent flow
- Other common factors
How Does It Appear?
How Does It Appear?
How Does It Appear?
How Does It Appear?
How Does It Appear?
ANAEROBIC BACTERIA
The development of $\text{H}_2\text{S}$ Gas

$H_2S \leftrightarrow HS^- + S^{2-}$

$SO_4^{2-} \rightarrow H_2S$
H$_2$S Gas Concentrations
A 3 Stage Process

Phase I  Phase II  Phase III

Surface pH vs. Age
A 3 Stage Process

Concrete Manufactured
pH 12.5 - 14

Phase I
Carbonation and Lowering of Surface pH to 10 -11

Phase II
Biofilm Becomes Established, lowering the pH to 4 - 6

Phase III
Surface pH Drops with Exposure to H₂S which Produces Acid Resulting in Severe Corrosion

Surface pH

Age

Precast... The Concrete Solution

NPCA
Carbonation
Phase I – Carbonation and Lowering of pH

• Carbonation: dissolution of CO$_2$, movement through pore solution and reaction with Calcium Hydroxide (CH) to form CaCO$_3$

• CH helps to keep the pH in concrete high

• pH can be lowered by fluids in contact with the surface that dissolves CH
A 3 Stage Process

Phase II Biofilm Becomes Established lowering the pH to 4 - 6

Surface pH

Age

Precast ... The Concrete Solution
Phase II - Attachment

Phase II - What can be done?

• Rate of attachment and succession will depend on bacteria's “happiness”
  – Temperature – The cooler the better
  – Surface texture – Application of sealers to reduce surface roughness
  – Moisture – Dry walls will have few bacteria
  – Availability of nutrients – Likely provided by other microorganisms
A 3 Stage Process

Phase III
Surface pH Drops with Exposure to H₂S which Produces Acid Resulting in Corrosion
Phase III - Corrosion

- Phase III
- Surface pH drops with exposure to H₂S which produces acid resulting in corrosion.

- pH > 5
- pH ~ 1.0 - 1.5
- pH < 1 - 1.5

H₂S
Phase III - Corrosion

- pH ~ 5
  Concrete Not Likely to Deteriorate

- pH ~ 1.5 - 5
  Potential Mixture Modifications (SCM, Cem. Type)

- pH < 1-1.5
  Degradation
Hydrogen Sulfide

Wastewater containing sulfates

Anaerobic bacteria reduce sulfate to sulfide

Sulfide mixes with water to form hydrogen sulfide
Phase I – Carbonation and pH Reduction

Carbon Dioxide and water form carbonic acid

Carbonic Acid reacts with concrete above water level

pH of Concrete is reduced to about 10-11
At ~ pH 9 and less, thiobacillus bacteria colonize

H2S provides nutrients for aerobic bacteria

Thiobacillus consume H2S and excrete sulfuric acid

Different strains of Thiobacillus live and die off
Phase III - Corrosion

Sulfuric acid reacts with calcium hydroxide

This reaction forms gypsum

Gypsum further reacts with the aluminates

Ettringite is a gel that expands with water contact

This reaction forms ettringite
The Purdue Study

- We made 12 samples of varying mix designs
- A Biological Growth Chamber was constructed
The Purdue Study

• Bacteria was obtained
Concretivoros
The Purdue Study

Bacteria was obtained...
The Purdue Study

• Acid Immersion Test
The Purdue Study

Acid Immersion Test
Purdue Study Conclusions

- MIC is a three-stage process that relates to bacterial growth and the surface pH inside the tank above the liquid level.
- Devising a testing protocol that mimics an environment in which MIC could thrive is very dangerous, difficult to maintain and difficult to control.
- The development of a single comprehensive test method to evaluate concrete resistance to MIC is inherently complex. It may be more useful to investigate each of the three stages separately.
- Use of SCMs, Limestone show benefits
what's next?
Next Steps

• Developing testing protocol for field studies, testing of proprietary products, ASTM test methods and the effects of other variables such as venting.

• Developing information for our members and industry.
Testing Protocols

• **Stage I**
  – Not much to do. Carbonation will occur. Not detrimental

• **Stage II**
  – Studies attachment and growth potential
  – Important for admixtures and sealers

• **Stage III**
  – Acid immersion studies
  – Fix test gray areas
Field Study

- Field data will be useful to determine how the field corrosion rate matches the environment.

- Temp/RH Probe
- H₂S Meter
- Surface pH Meter
Three Ways to Improve Concrete’s Resistance to Acid Attack

1. Employing the right concrete composition to make it as impermeable as possible

2. Isolating it from the environment by using a suitable coating or

3. Modifying the environment to make it less aggressive to the concrete
Three Ways to Improve Concrete’s Resistance to Acid Attack

1. Employing the right concrete composition to make it as impermeable as possible
Three Ways to Improve Concrete’s Resistance to Acid Attack

1. Employing the right concrete composition to make it as impermeable as possible

- W/C Ratio
- Cement Content & Type
- Suitable Aggregates
- Aggregate Gradation
- Water Quality
- Admixtures / Additives
- SCM’s
Three Ways to Improve Concrete’s Resistance to Acid Attack

1. Employing the right concrete composition to make it as impermeable as possible

   - Mix workability
   - Consolidation
   - Batching & Placing Process
   - Curing
Three Ways to Improve Concrete’s Resistance to Acid Attack

1. Employing the right concrete composition to make it as impermeable as possible

2. Isolating it from the environment by using a suitable coating

3. Modifying the environment to make it less aggressive to the concrete
Summary

• MIC is not everywhere.
• Sulfates to Sulfides to Aqueous $\text{H}_2\text{S}$ to $\text{H}_2\text{S}$ Gas
• 3 Stage Process
• Test Protocols and Field Studies next
• Producer need to focus on low w/c ratio, high strength, dense concrete
• Use us as a resource!!!
Additional Information & Resources

NPCA website

http://precast.org/

Visit us at booth 5462
Questions?

• If you have any questions about this presentation please contact:

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THANK YOU!