What's Wrong with My Concrete? Fix It!
Using Concrete Petrography to Determine Cause & Extent of Concrete Deterioration

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Original Working Title:

Petrographic Report on My Cores: WTF??
LEARNING OBJECTIVES

• Modes of concrete failure
• To understand the role & limits of concrete petrography to determine the cause of concrete failure
• Interpretation of the appropriate repair method
• To select the appropriate repair material
ACKNOWLEDGEMENTS

Photo credits: Euclid Chemical, WJE, DRPC Inc.

On the shoulders of giants:

Richard C. Mielenz
Bryant Mather
Katherine Mather
Bernie Erlin
L. Brad Shotwell
CONCRETE PETROGRAPHY & REPAIR

• Determine the cause of deterioration
• Determine the extent of deterioration
• Determine the repair method & material
• Repair!
WHAT IS CONCRETE PETROGRAPHY?

- Applies standard geologic microscopy techniques and methods to analyze concrete and concrete raw materials
- Examinations of hardened samples and raw materials follow ASTM C 856, C 457 & others
- Investigative choices based on experience and competence of Petrographer
- Provide definitive answers in limited time
WHAT IS CONCRETE PETROGRAPHY?

- Rapid means of analysis using geologic laboratory techniques
- Mainly troubleshooting - “After the fact” Why? How bad is it?
- There are limitations: “Can Do” and “Can Not Do”
- Constraints include adequate sample size and adequate field information
CONCRETE PETROGRAPHERS ARE:

• Geologists
• Know how to use the equipment
• Know the prep and test procedures
• Know concrete materials, practices and impact of practices on concrete
• Know how to interpret the findings
SOME INSTRUMENTS ARE DECIDEDLY LOW TECH... OTHERS ARE NOT...
CONCRETE PETROGRAPHY--TOOLS AND EQUIPMENT

Rock saw

Lapidary wheel

Courtesy of DRPC Inc.
CONCRETE PETROGRAPHY--TOOLS AND EQUIPMENT

• Stereomicroscope
  – for visual examination

• With point count stage
  – for air void system analysis

Courtesy of FHWA.gov
CONCRETE PETROGRAPHY--TOOLS AND EQUIPMENT

• Thin section machine
• Miscellaneous chemicals, reagents and standard lab procedures

Courtesy of DRPC Inc.
CONCRETE PETROGRAPHY --
TOOLS AND EQUIPMENT

- Petrographic microscope (plane polarized light) and index oils

Courtesy of DRPC Inc.

Courtesy of SPI.

Courtesy of Iowa State
CONCRETE PETROGRAPHY--TOOLS AND EQUIPMENT

• Scanning electron microscope
• Energy dispersive spectroscope

Courtesy of DRPC Inc.
CONCRETE PETROGRAPHY--TOOLS AND EQUIPMENT

X-ray diffractometer

Figure 1. XRD pattern of C3S hydrated for 28 days. C3S: calcium silicate, CH = Ca(OH)$_2$. 
Q: WHAT IS IMPORTANT INFORMATION TO A PETROGRAPHER REGARDING YOUR CONCRETE?

A: EVERYTHING!
TEST REQUEST FORMS SHOULD INCLUDE:

- Mix design information
- Details of the problem
- Observations - just the facts
- Conditions
- Plastic properties
- Placement and finishing details
- Sample info - ID, location, ...
- Photographs if available
LIMITING FACTORS & CONSTRAINTS

• Adequate sample size: *Is it representative?*
• **Information from the field** is *KEY* to better answers, more useful reports!!!
• Service conditions
• Other pertinent information (heaters, equipment breakdowns, sudden rainstorm...)
• Quality of the report reflects the quality of information provided
PETROGRAPHIC REPORT CONTENT

• INTRODUCTION
• METHODS & EQUIPMENT
• OVERALL CONDITION - Top-to-Bottom
  • Finished surface
  • Air-void content
  • Cementitious matrix
  • Aggregates
• DISCUSSION
• CONCLUSION
• **ICRI Technical Guidelines**
  - Sixteen guidelines published
  - Most popular is No. 03732 Surface Preparation Guide and surface profile chips
  - See Publications Catalog for a full listing of guidelines

• **Concrete Repair Manual**
  - Includes 80 documents on concrete repair
  - Now in its 3rd Edition

• **Other Documents**
  - ICRI sells other industry documents on concrete repair
“The probable cause of the reported low compressive strength was poor or inadequate curing.”
THE PETROGRAPHER SEES:

- Carbonated cement paste at & near surface
- In extreme cases, carbonation throughout

Stereomicroscope

Petrographic microscope

Courtesy of DRPC Inc.
THE FIX

OPTIONS

• Reactive silicate sealer/densifier
• Remove weak surface to hard, sound concrete, treat with reactive densifier
• Remove weak, dusty concrete the top with overlayment or topping mix
WHEN A PETROGRAPHER SAYS:

“The probable cause of the reported low compressive strength was an excessive air content.”
THE PETROGRAPHER SEES:

1% air = 3 - 5% $f'_c$

Stereomicroscope

6 % by vol.
4700 psi

10 % by vol.
3800 psi

16 % by vol.
2700 psi

Courtesy of DRPC Inc.
THE FIX

• Air cannot be removed from hardened concrete!

• Treat with reactive silicate sealer/densifier
• Use silane sealer to minimize ingress of water

These are stopgap measures until removal & replacement can occur.
Q: WHAT EFFECT DOES HIGH AIR CONTENT HAVE ON CONCRETE PROPERTIES?

– Strength reduction (Compressive, Flexural)
– Increased porosity
– Decreased abrasion resistance
– ... Compromised engineering/ performance properties
"The probable cause of the reported low compressive strength was excessive retempering."
THE PETROGRAPHER SEES:

- Veneers of lower w:cm ratio paste adjacent to c. aggs.
- Clustered air voids

Stereomicroscope

Courtesy of DRPC Inc.
RETEmPERING
THE FIX

• Air cannot be removed from or redistributed in hardened concrete!

• Treat reactive silicate sealer/densifier

• Use silane sealer to minimize ingress of water
WHEN A PETROGRAPHER SAYS:

“The probable cause of the reported low compressive strength was freezing of the concrete while plastic.”
THE PETROGRAPHER SEES:
Bladed ice crystal casts on the form/finished surface, in cement paste, in aggregate sockets
THE FIX

• Remove & replace
• Remove weak concrete then top with overlayment or topping mix
• Reactive silicate sealer/densifier
• Grind to hard, sound concrete, treat with a reactive densifier
WHEN A PETROGRAPHER SAYS:

“The probable cause of the scaling was inadequate air-entrainment.”
THE PETROGRAPHER SEES:
No or poorly distributed air.
THE FIX

• There isn’t one
WHEN A PETROGRAPHER SAYS:

“The probable cause of the delamination was premature or over finishing.”
THE PETROGRAPHER SEES:

- No air in the top ¼- ½ “, air entrainment in the bulk of the sample
- Incipient scaling or large voids/failure planes below finished surface
- Terminated bleedwater channels
- Bleedwater collection points
SCALING DUE TO OVERFINISHING
THE FIX

• Remove delamination zone, retop with microtopping, overlayment or topping mix
MICROTOPPING
WHEN A PETROGRAPHER SAYS:

“The probable cause of the cracking was...”
Q: WHAT ARE THE CAUSES OF CRACKS IN CONCRETE?

- Plastic shrinkage
- Drying shrinkage
- Re-entrant
- Shear
- Crazing/alligator
- Expansive reactions
- Overload/underdesign: +/- moment
- Corrosion of reinforcement

...
Identify the cause of the crack

- Crazing
- Plastic
- Positive moment
- Shear
- Negative moments
- Drying shrinkage
- Sawcut too late
- Settlement
- Re-entrant corner
- Over keyway
- Tee joint
- Curl
- Joints too far apart
- Corrosion
- Long narrow panel
- Between bolsters
- Anodic ring
DESCRIBING CRACKS

- Pattern vs. isolated
- Shallow vs. through
- Active vs. dormant
- Structural vs. non-structural
- Plastic vs. hardened
PLASTIC SHRINKAGE CRACKING
CRAZING CRACKS
THE FIX

• Urethane sealant
• Epoxy injection
• Ultra LV penetrating epoxy
• Crack healer/sealer (hybrid urethane, mma)
Q: HOW ARE MOST CRACKS REPAIRED?

- Rout & fill
- Epoxy injection /gravity fill
- Urethane sealants
- Crack mender- hybrid urethane
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QUESTIONS, COMMENTS, COMPLAINTS?
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