Application of Petrography to Highway Materials

Hosted by
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chair, TRB Committee AFP70 “Aggregates”
Your presenters

• **Steven J. Stokowski, P.G.**
  – Principal Petrographer, TEC Services

• **D. Stephen Lane**
  – Research Scientist, Virginia D.O.T.
Today’s Content

• Concrete, Asphalt, Masonry
  – Steven J. Stokowski

• Training, Literature, Soils, Major Contributors
  – D. Stephen Lane.
Petrography

- Petrographic examination is a visual examination and analysis in terms of both lithology and properties of the individual particles. The procedure requires use of a hand lens and petrographic and stereoscopic microscopes. Less commonly, X-Ray diffraction or differential thermal analysis supplement the microscopic examinations.

  R.C. Mielenz, 1966
Professional Requirements

Knowledge of:

• Physical, chemical, and optical properties and characteristics of rocks, minerals, and materials
• Composition and design of construction materials
• Behavior of materials in varied environmental settings

Capabilities:

• Describe and interpret the facts in writing
• Predict what could and did occur
Petrographic Manual

Petrographic Methods of Examining Hardened Concrete: A Petrographic Manual
Publication No. FHWA-HRT-04-150
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VTRC - Virginia Transportation Research Council

FOREWORD

Petrographic Methods of Examining Hardened Concrete: A Petrographic Manual was originally published in 1992 by the Virginia Transportation Research Council (VTRC) as Report VTRC-92-R14. Authored by Holli N. Walker, it was the culmination of a quarter century of work by her in concrete petrography at the VTRC.

This edition, revised by D. Stephen Lane, senior research scientist at the VTRC, builds on the original work. It has been revised and updated to reflect recent advances in techniques and work in concrete petrography. Major additions to the manual include a new chapter (chapter 14, written by Paul E. Stutzman, physical scientist, National Institute of Standards and Technology) on the use of the scanning electron microscope to examine concrete and concretesmaling materials, and additional information on the identification and classification of rocks and minerals in aggregates (appendix D). Chapter 10, Alkali-Aggregate Reactions, was reorganized to outline the process one would follow to investigate a case of concrete deterioration and illustrate the features that provide evidence of alkali-silica or alkali-carbonate reactions. It is hoped that the manual will be of great use both to those entering the field of concrete petrography and to the experienced petrographer.

Hand Lenses, Petrographic Microscope
Petrography, ASTM C856 Standard Practice
Polarized Light, SEM, EDX

Optical

SEM/BSE

SEM / EDX
C457 Standard Method Instruments
Application to Highway Materials

• Raw Material Characterization
  – Aggregate, Dimension Stone, Bedrock, Soil
  – Cementitious Materials
  – Recycled Materials

• Performance Investigations
  – Highways
  – Bridges
  – Tunnels
  – Incidental Construction
Application to Highway Materials

• Raw Material Characterization
  – Aggregate, Dimension Stone, Bedrock, Soil
  – Cementitious Materials
  – Recycled Materials
SUMMARY

The sand product is suitable for use in Portland cement concrete with a lengthy design life. There is no significant potential for an alkali-aggregate reaction if used in a continuously moist concrete compounded with high-alkali cement, other high-alkali cementitious materials. No further testing for potential reactivity is required for this aggregate.

This product is a natural sand composed primarily of single grains of quartz that are not considered to be potentially alkali-reactive. The sand also contains feldspar, mica, garnets, heavy minerals and fragments of granitic rocks and schists. Optically strained quartz within the fragments of granitic rocks and schists (approximately 2.6% of the volume of the total aggregate) is within the limits (5.0%) established by the Massachusetts Highway Department in Section M4 of the Standard Special Provisions for Cement and Cement Concrete Materials.
Cementitious Materials
Polymer Asphalt

Lesueur, D., 2009, The colloidal structure of bitumen: Consequences on the rheology and on the mechanisms of bitumen modification

Application to Highway Materials

• Performance Investigations
  – Highways
  – Bridges
  – Tunnels
  – Incidental Construction
Application to Highway Materials

• Performance Investigations
  – Highways
    • Earthwork & Fill
    • Cut slopes
    • Granular Base
    • Pavement
      – Hydraulic Cement Concrete
      – Asphalitic Concrete
Highways

- Earthwork and Fill Material
  - Heaving, Acid Drainage

- Swelling clays
- Gypsum/anhydrite
- MgO-rich slag
- CaO-rich fly ash, slag
- Sulfide Minerals (iron pyrites)
Fill-Related Pavement Heave
Bristol, VA
Fill Related Pavement Heave
Bristol, VA

Improper Use of Borrow
Cut Slopes - Disruption of Soils with Sulfide Minerals, Fredericksburg, VA

Associated/Continuing Problems:
• Acid drainage damaging plants, concrete, metals
• Sulfate attack of concrete
• Heave of lime-stabilized soils
Highways

- Granular Base
  - Heaving, Degradation, Compacted Stability

- Gravel vs. Crushed Gravel

- Crushed Stone
  - Clay in weathered rock, altered basalt or shale

- Crushed Concrete
  - Calcite in drains

- Crushed Slag (free MgO, CaO)
  - Heaving
Highways

• Pavement
  – Hydraulic cement concrete
    • Composition
    • Consolidation
    • Air-entrainment, freeze-thaw damage
    • ASR/ACR
    • D-cracking
    • Joint deterioration (rot)
    • Chloride attack of slag cement concrete
Air-Entrainment Data Collection
Linear-Traverse / Point-Count

<table>
<thead>
<tr>
<th>CA%</th>
<th>FA%</th>
<th>P%</th>
<th>Air%</th>
<th>SF(mm)</th>
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<td>22.0</td>
<td>32.8</td>
<td>10.6</td>
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ASR/ACR Manifestations

Expansion & Closing of Joints
In Bridge Decks, Jersey Barriers, etc.

Map Cracking of Pavement, Retaining Walls, etc.
ASR Distress

Macro to Micro Scale
ASR Diagnostics
ACR Diagnostics

Peripheral Rims

Characteristic texture

Dedolimitization to form Brucite & Calcite

Internal Cracks
Highways

• Asphalt Concrete
  – Polymer modification of asphalt (UV fluorescence)
  – Mica content of manufactured sand (GA DOT)
  – Absorption of asphalt by aggregate
  – Aggregate quality and performance
  – Compactability during construction
  – RAP/virgin AC homogenization
HMA Pavements - Aggregates

Shale

Dusty

Dolomite
HMA Compaction

Cold Surfaces

Broken Aggregate
HMA Investigations

HMA Microscopy, Denmark

FHWA, 2004, Superior Materials, Advanced Test Methods, and Specifications in Europe

Navaro, J. et al, 2012, Observation and evaluation of the degree of blending of reclaimed asphalt concretes using microscopy image analysis

Poulikakos, L., & Parti, M, 2009, Evaluation of moisture susceptibility of porous asphalt concrete using water submersion fatigue tests
Bridges

- Substructure, Columns
  - Mass Concrete
  - Masonry
  - Shotcrete and other Repairs
  - Use of dimension stone and sculpture

- Decks
  - Lightweight concretes
  - Overlays (LMC, SFC), Repair Materials

- Beams
  - Precast – DEF
Drilled Shaft for a Bridge

Tremie Concrete, lost tremie & mixed with water
Masonry Bridges
Shotcrete Repair, Triboro Bridge, NY
ASR
Fore River Bridge, MA
Manhattan Bridge Sculpture, NY
Bridge Deck Repairs, Pyrament, Tappan Zee Bridge, NY
Collision, Fire Damage, Richmond, VA
Tunnels

• TBM Performance in rock
  – Penetration rates and abrasion
• Linings
• Mass Concrete
• Pavement
• Fire resistant panels and attachments
Lincoln Tunnel, NY
Incidentals

• Incidental Construction
  – Road markings
  – Crash barriers
  – Sound Barriers
  – Pavers
  – Curb and Gutter
  – Light poles
  – Drainage structures
  – Flowable Fill
Major Contributors to Petrography for Highway Applications

- R.C. Mielenz, W. DePuy, USBR
- B. Mather, K. Mather, USAE
- B. Erlin, PCA & Erlin-Hime
- L. Dolar-Mantuani, *Handbook of Concrete Aggregates, 1983*
- M. Ozol, VDOT & Martin Marietta
- P. Grattan-Bellew, NRC Canada
- H. Walker, VDOT
- C. Rogers, MTO
- G. M. Idorn, *Danish NIBR*
- Paul Stutzman, NIST
- D. St. John, A. Poole & I. Sims, *Concrete Petrography, 1998*
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