Applied Construction Geology to Maximize Pavement Performance

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What does an Iowa DOT Geologist Do?

Stratigraphy

Develop an in-depth working knowledge of the Geologic formations and their engineering properties.

Industry

Work with producers in the quarries, underground mines and gravel pits; and partner Specifications.

Determine Durability Classes for Portland Cement Concrete (PCC) aggregates

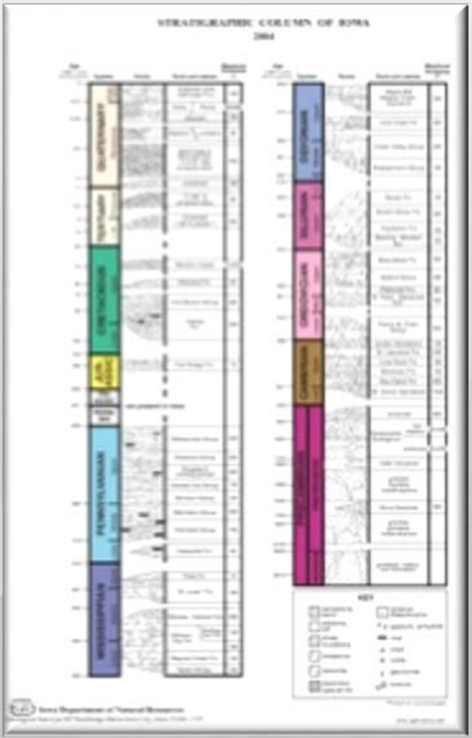
Analyze information obtained from Chemical and Physical testing.

Forensics

Pavement deterioration evaluations.

STRATIGRAPHY

- Iowa has a nearly complete sequence of Paleozoic strata.
- Regional Dip 3° dip NE – SW: Cambrian bedrock outcrops in NE Iowa, progressively younger to SW Iowa where Pennsylvanian bedrock outcrops.
- Glacial deposits overlay the bedrock.
  - Generically termed ‘Gravels’.
  - Thickest in Northwest Iowa



BEDROCK GEOLOGIC MAP OF IOWA
1998

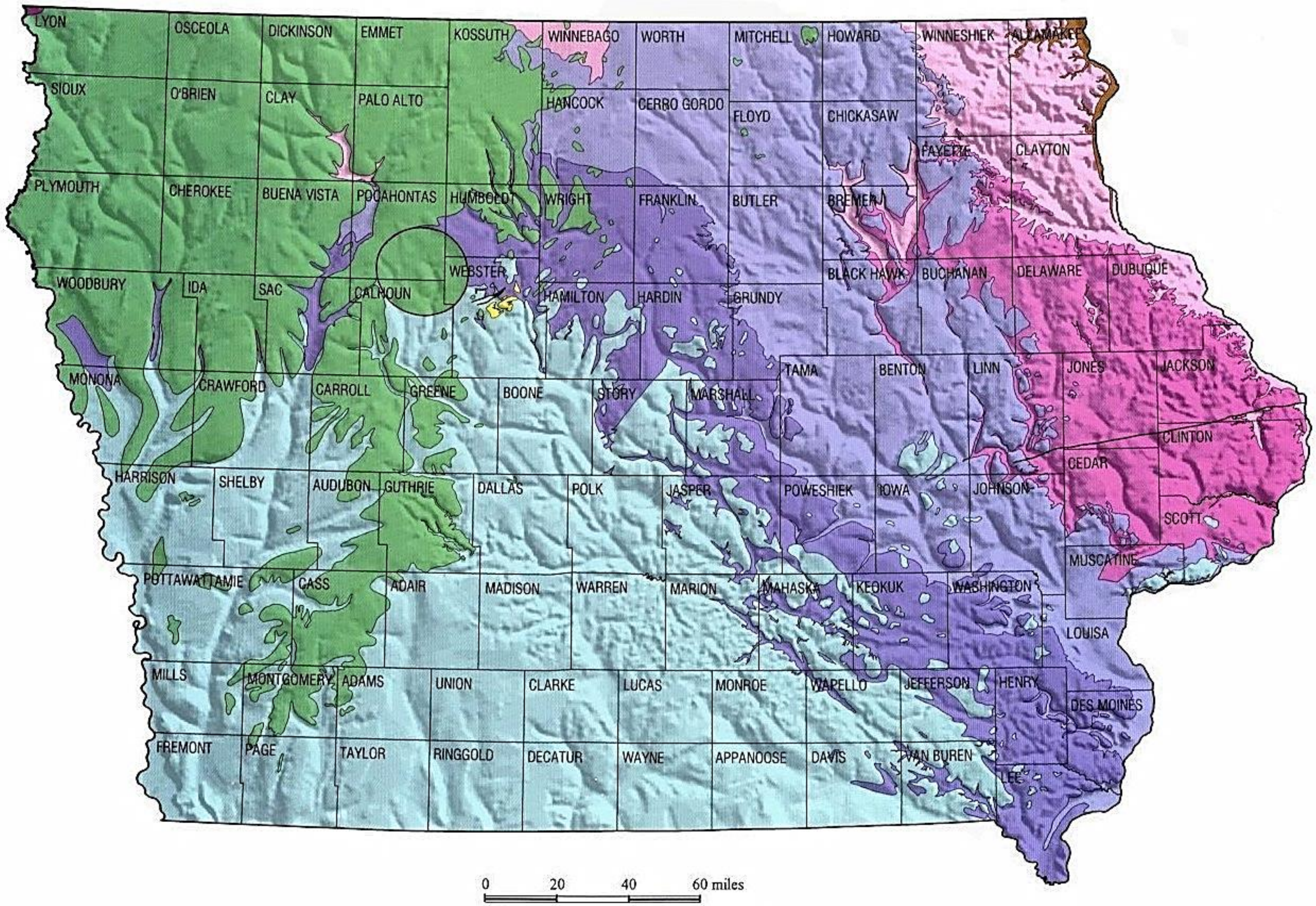
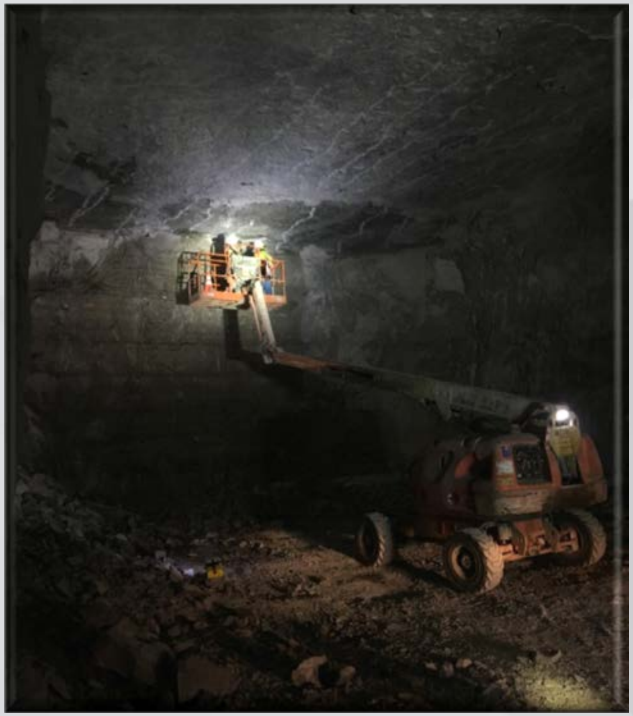
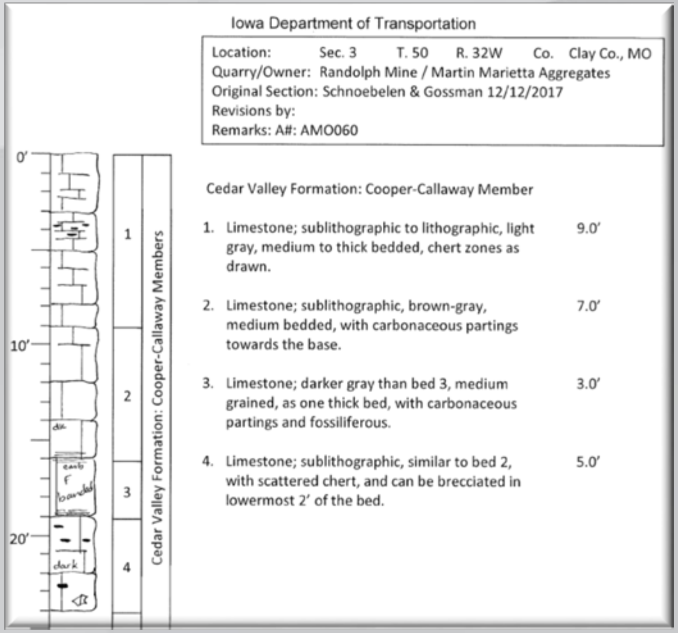


Image courtesy of Ray Anderson, Iowa Geological Survey

INDUSTRY



- Nearly 1000 active sources, in and around Iowa. See IM T203
- Provide geologic sections for active sources
  - Assist aggregate producers with ledge control



Iowa Department of Transportation

Location: Sec. 3 T. 50 R. 32W Co. Clay Co., MO
Quarry/Owner: Randolph Mine / Martin Marietta Aggregates
Original Section: Schnoebelen & Gossman 12/12/2017
Revisions by:
Remarks: A#: AMO060

Cedar Valley Formation: Cooper-Callaway Member

1. Limestone; sublithographic to lithographic, light gray, medium to thick bedded, chert zones as drawn. 9.0'
2. Limestone; sublithographic, brown-gray, medium bedded, with carbonaceous partings towards the base. 7.0'
3. Limestone; darker gray than bed 3, medium grained, as one thick bed, with carbonaceous partings and fossiliferous. 3.0'
4. Limestone; sublithographic, similar to bed 2, with scattered chert, and can be brecciated in lowermost 2' of the bed. 5.0'

- Partner specifications with Industry.

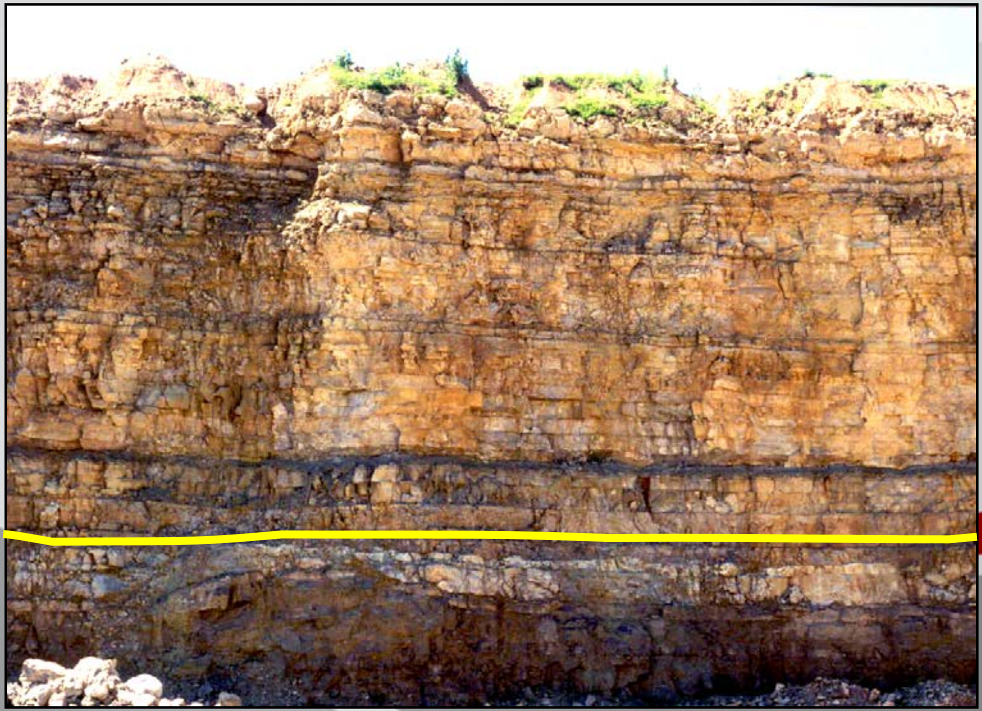
Southwest Iowa

Northcentral Iowa

VARIABILITY OF QUARRY LEDGES

Western Iowa

East Central Iowa



Southeast Iowa

Glacial "Gravel" Deposit

Determine Durability Classes for Portland Cement Concrete (PCC) aggregates

Using Salt-Susceptibility Quality Number and PCC Pavement Service History

Background

- Pavement failures in the mid 1980's led former DOT geologist Wendell Dubberke to:
  - investigate the causes for these failures (high DF)
  - develop an algorithm that combined the pore index with aggregate chemistry to predict durability class.
  - Algorithm was cross referenced to known pavement performance
- In 2000, the DOT began using SSQN as a concrete stone approval specification.
- After 10 years evaluation, current DOT geologist Bob Dawson made revisions to the algorithm.

Iowa DOT Durability Classes

3 Classes: 2, 3, 3i

- Class 2—minimal deterioration only after 20 years, non-interstate usage
- Class 3—minimal deterioration only after 25 years, non-interstate usage
- Class 3i—minimal deterioration only after 30 years, interstate usage

Principle Reasons for Aggregate Failure

- Clay content
- Pore system
  - Capillary pores yield many available sites for chemical reactions from deicing salts to occur
  - Poor freeze thaw performance
- Chemistry of the Aggregates
  - Stability of minerals that form the aggregate.
  - Unstable due to substitutions in the crystal lattice
    - Fe for Mg in $CaMg(CO_3)_2$

These three factors are evaluated by:

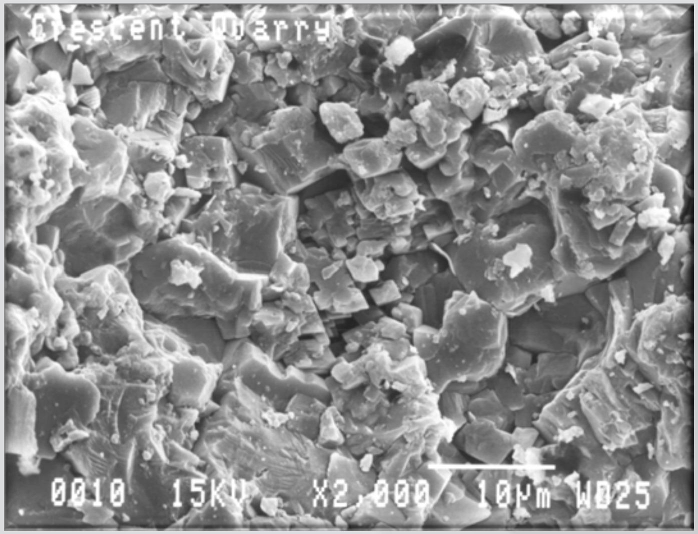
- Measuring the clay content of the aggregate (XRF, alumina quality number).
- Determining the pore system for pore size and volume (Iowa Pore Index quality number).
- Examining the limestone and dolomite fractions for chemistry and mineralogy (XRF/XRD quality number).

Iowa Pore Index Number

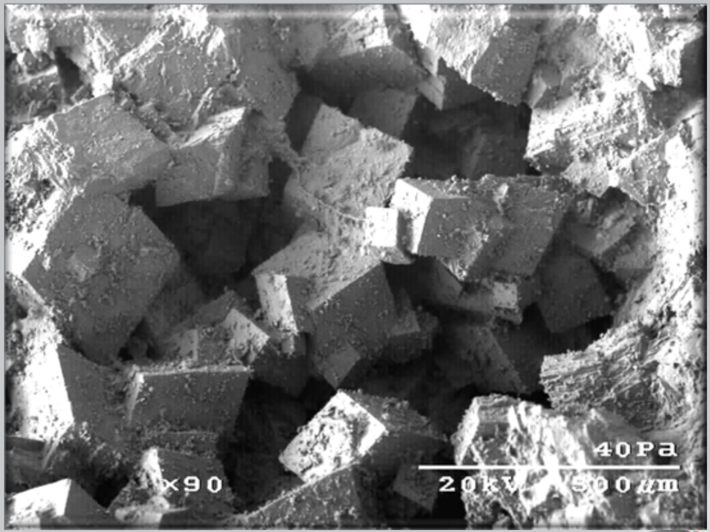
- This number quantifies the amount of water an aggregate particle absorbs into it’s pore system.
- The Pore System comprised of:

  Primary—large pores

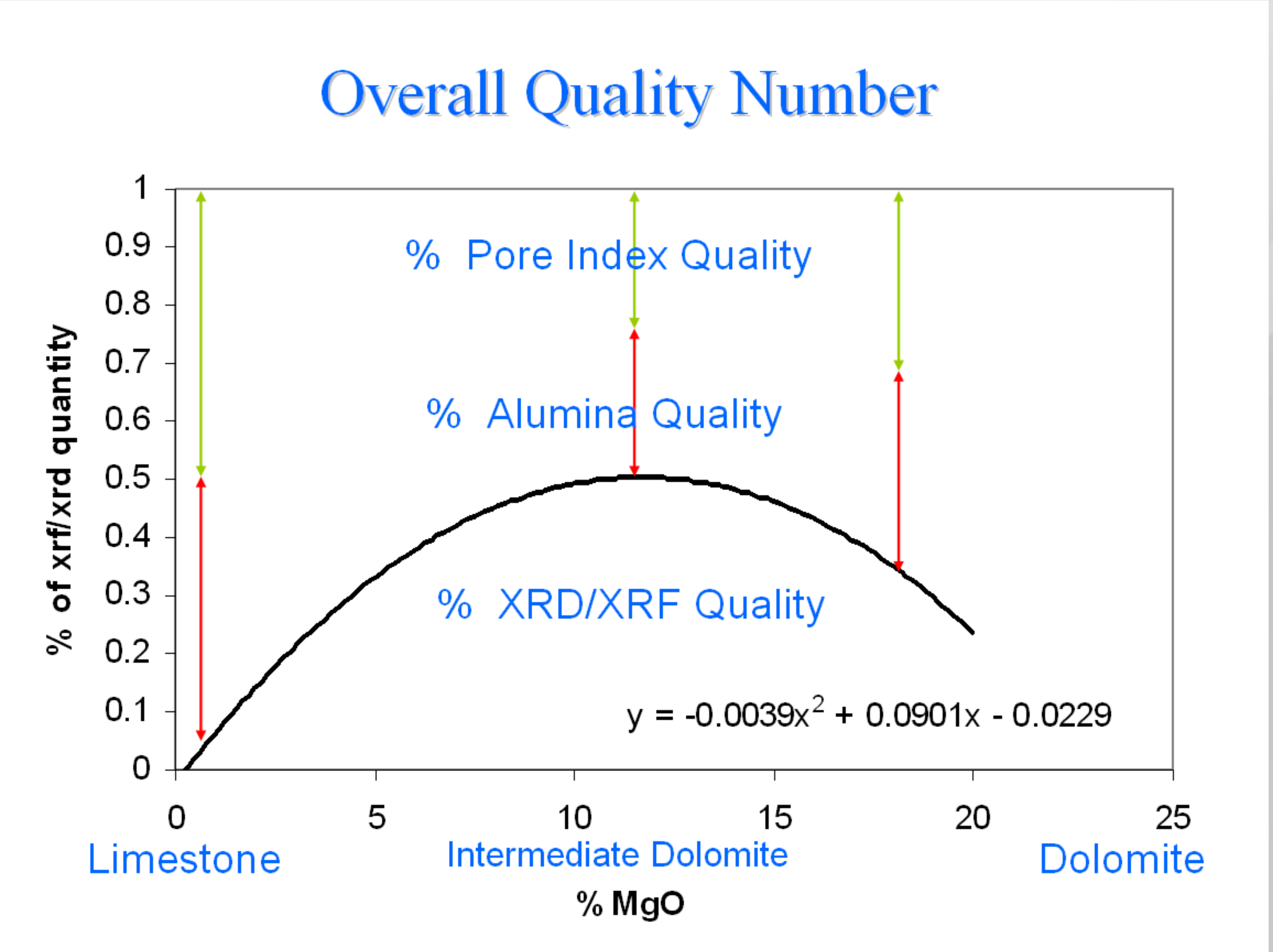
  Secondary—small, capillary pores



SEM Image on left (5000X); grain size of a poor performing aggregate.
SEM Image on right (90x); grain size of a good performing aggregate.



OVERALL SALT-SUSCEPTIBILITY QUALITY NUMBER



Graphical representation and equation showing the proportional fraction that the XRF-XRD quality number has in the salt-susceptibility quality number based on how dolomitic the aggregate is.

States Where Iowa DOT Testing Methods are used or have been used.

Iowa Pore Index Test (AASHTO TP120-16)

- Kentucky
- Michigan
- Minnesota
- Missouri
- Montana

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Standard Method of Test for Pore Index for Carbonate Coarse Aggregate

AASHTO Designation: TP 120-16[1]

Release: Group 3 (August 2016)

AASHTO

1. SCOPE

1.1. This test method covers the determination of the pore index values for carbonate (limestone and dolomite) coarse aggregate for Portland Cement (PC) Concrete.

1.2. The values stated in SI units are to be regarded as the standard.

1.3. *This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- T 27, Sieve Analysis of Fine and Coarse Aggregates

3. SUMMARY OF TEST METHOD

3.1. The method uses water pressure at 240 kPa (35 psi) to force water into the aggregate pores. A measurement is made of the volume of water that is forced into the aggregate during a period between 1 min and 15 min after application of the pressure.

4. SIGNIFICANCE AND USE

4.1. The pore index test is used to quickly assess the pore system of carbonate coarse aggregates and identify potential freeze-thaw durability issues for use in PC Concrete.

4.2. Carbonate aggregates with secondary pore index values of 20 or below have a pore system that is

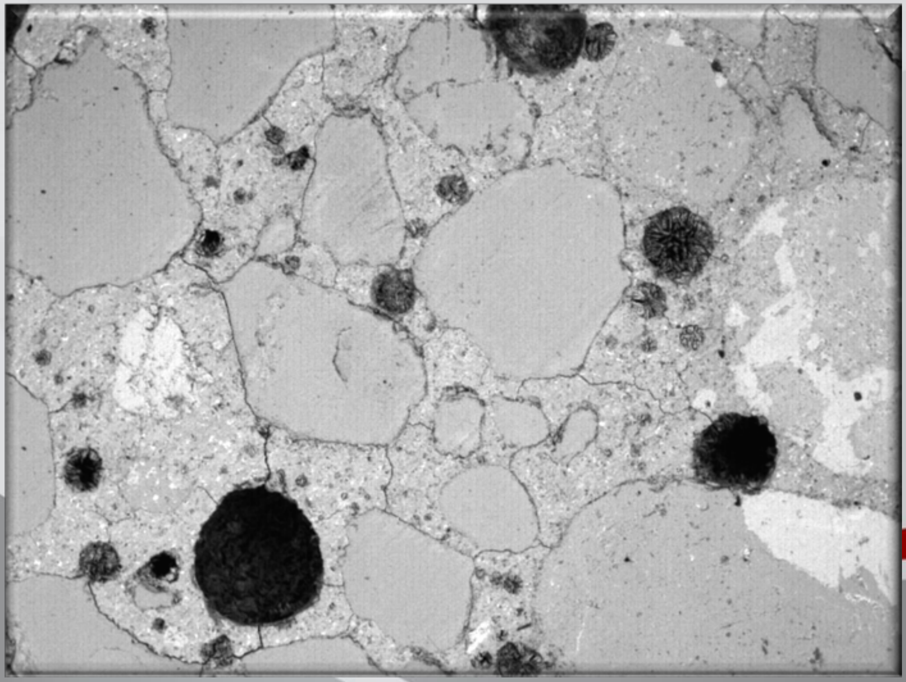
XRF (Alumina) Evaluation

- Missouri
- Florida
- Michigan

A recent FHWA Nationwide review of state DOT's, recognized the Iowa DOT for having *THE* best system for determining the quality of aggregates used in construction projects.

We're the only state in the Nation that addresses salt-susceptibility in construction aggregates.

Forensics for Pavement Service History

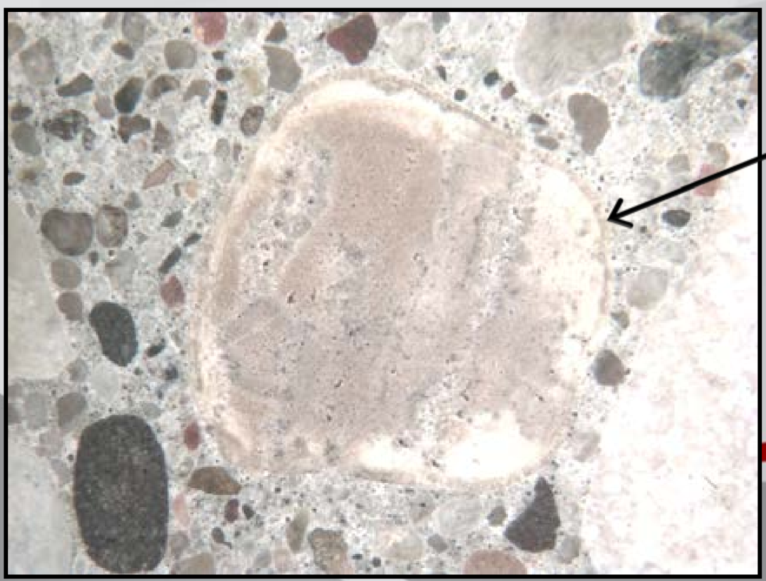


Extremely D-cracked pavement from Salt-susceptible Aggregate

US Hwy 30 Carroll County, 30+ years with no aggregate related deterioration

Side views from a recent pavement evaluation showing what D-cracking looks like below the pavement surface.

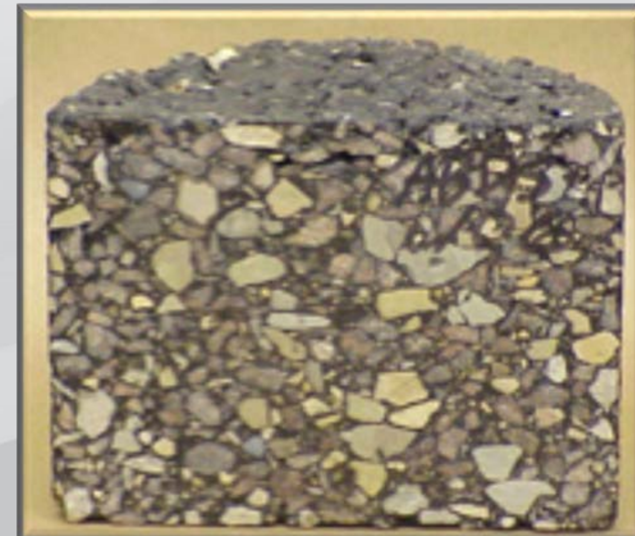
Staining in the cement paste. ACR?



Salt Reaction Rim on an Aggregate Particle

WHY IS AGGREGATE IMPORTANT?

It’s the primary component of PCC, HMA, and granular surfacing materials.



PROJECT EXAMPLE

US Hwy 20 from Moville to Galva – Approx. 24 miles

550,000 Total Tons of Aggregate used in 2016

- 25,000 Tons of Floodable Backfill
- 150,000 Tons of Granular Subbase
- 100,000 Tons of Granular Backfill
- 100,000 Tons of Special Backfill
- 70,000 Tons of 1" PCC Rock
- 70,000 Tons of Sand for PCC
- 15,000 Tons of Intermediate PCC
- 20,000 Tons of Reclaimed/Recycled Aggregate

*Based on current production to complete the "Final Forty"… these projects will use just over **2 million tons** of aggregate.*

- *Estimates courtesy of Dist. 3 Materials staff.*


QUESTIONS
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