Troubleshooting Inadequately Cured Concrete or Why Did my Concrete Scale?

Iowa Better Concrete Conference

Iowa State University

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American Engineering Testing, Inc.
Reasons for Scaling of Exterior Concrete Flatwork

1. Poor overall air content
   a. No air entrainment
      • batching error
      • wrong mix delivered
   b. extended time before placement
Reasons for Scaling of Exterior Concrete Flatwork

2. Poor finishing practices
   a. Over-finishing
   b. Working water into the surface
   c. Retempering/excessive w/cm
   d. Inadequate curing
      • Late
      • Incomplete
Reasons for Scaling of Exterior Concrete Flatwork

3. Late season placements (premature service) – lack of durability strength

4. Exposure to Salt hastens distress
   a. Lowers freezing temp of water
   b. Critical saturation due to osmosis
   c. Produces a specific environmental condition
   d. Who’s fault?
   e. …concrete was already compromised
1994-1997 Freeze-Thaw Cycles & Precipitation

Cycle Low temp ≤ 28
Precip. only Oct Nov Dec

F-T Cycles (#) | Precip (in)
--- | ---
1994-1995 | 60 | n/a
1995-1996 | 74 | 25.7
1996-1997 | 57 | 45.52
1998 ARMMN Study After 96-97

33 Core Samples

Air Problems 21% total
  - Low air 15%
  - No air 6%
Over-finishing 48%
Inadequate Curing 61%
Long Haul Time (>45min) 42%
High w/cm (>0.45) 39%
Late Season Placement 15%

1994-1997 Freeze-Thaw Cycles & Precipitation
2011-2014 Freeze-Thaw Cycles & Precipitation

- **2011-2012**: 65 F-T Cycles (#), 9.3 Precip (in)
- **2012-2013**: 69 F-T Cycles (#), 19.3 Precip (in)
- **2013-2014**: 52 F-T Cycles (#), 22 Precip (in)
2015 ARM Study After 13-14

16 Core Samples

- Low air: 13%
- Over-finishing: 13%
- Inadequate Curing: 44%
- w/cm <0.45: 100%
- Late Season Placement: 31%

2011-2014 Freeze-Thaw Cycles & Precipitation

<table>
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2020-2023 Freeze-Thaw Cycles & Precipitation

- 2020-2021: 57 F-T Cycles, 34 Precipitation (in)
- 2021-2022: 51 F-T Cycles, 27.5 Precipitation (in)
- 2022-2023: 73 F-T Cycles, 37.6 Precipitation (in)
PETROGRAPHY

Microscopical analysis of concrete and aggregates
PETROGRAPHY

ASTM’s
C856
C457
C1723
PETROGRAPHY

Core Sampling
Preparation of lapped and thin sections
Various microscopes
Over-finishing
Mortar Flaking
40 year old airfield pavement
SEM ANALYSIS

OPC Paste

CSH (fuzzy)

Ettringite (needly)

Ca(OH)$_2$ (tabular crystals)

Pore solutions > pH11
SEM ANALYSIS
Carbonated Paste

- Completely different microstructure
- $\text{CaCO}_3$ like material
- ..with residual Si, Al, Fe
- Very little ettringite
- Pore solutions close to neutral pH 7
North Dakota, 2016
North Dakota, 2013
Heavy Civil Paving

- Lower w/cm
- Comprehensively enforced
- Timely
- Curing method
New Bridge – NE USA
Spring 2014
Portland Limestone cement (PLC)
Correlation: Porosity – Compressive Strength (exp. Data by D. Herfort, Aalborg cement)

- **Compressive strength** measured
- **Total porosity** calculated

Relative change of porosity and compressive strength [%]

Amount of CaCO₃ added [wt.-%]
2020-2023 Freeze-Thaw Cycles & Precipitation

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Thank you!