



American Concrete Institute

Nano Silica in Concrete Bridges and Pavements for Indiana Department of Transportation

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THE WORLD'S GATHERING PLACE FOR ADVANCING CONCRETE





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Over 25 Years of Work in The Heavy Highway Industry
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Abstract – The following presentation will cover an overview of case studies, to include means and methods for the use of nano silicas in concrete transportation systems. Problems encountered in previous conventional concrete, and solutions provided by the incorporation of nano silicas in concrete for Indiana Department of Transportation projects.

The Bad & The Ugly!



Problems With The Old;

- Pop Outs!
 - Silica Fume Dispersion
 - Bag Corners
- Cracking
 - Plastic Shrinkage
- Wet Cure Limitations
 - 7 Days (Done Right)
- Finishability
 - “Sticky”
 - Using Evaporation Retarders As Finish Aids!
- Pumpability
 - Higher Pump Pressure



.....Paved With Good Intentions.

SECTION 702 – STRUCTURAL CONCRETE

702.01 Description

This work shall consist of furnishing and placing portland cement concrete for structures and incidental construction in accordance with 105.03.

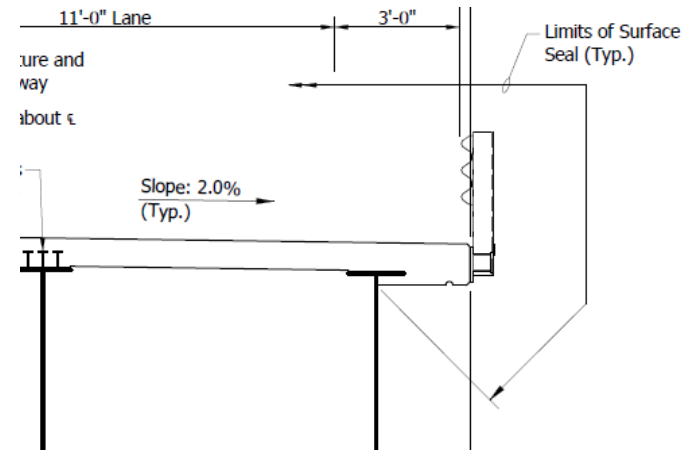
702.02 Classes of Concrete

The following classes of concrete shall be used where specified.

10	Class of Concrete	A	B	C
	Cement content in lbs/cu yd	564	470	658
	Maximum water/cement ratio in lbs of water per lbs of cement	0.490	0.620	0.443

Unless specified otherwise, the concrete used shall be class A. When class A is specified, class C may be used as a substitution. When class B is specified, class A or class C may be used as a substitution.

2016 INDOT Standard Specification



- Maintenance Schedule
- Contractor Vs INDOT Maintenance Crews
- Generally Accepted Principles

.....Paved With Good Intentions. (Part Deux)

(c) Alternate to Concrete Sealers

80 In lieu of concrete surface sealing for concrete barrier wall, bridge decks, reinforced concrete bridge approaches, pier and bent caps, bridge railing, and bridge railing transitions, an alternate concrete mix design may be used.

The concrete mix design shall be as specified, except either 3% silica fume by weight of cementitious material shall be added to the mix design or 30% ground granulated blast furnace slag substitution based on the required cement content shall be incorporated into the mix. The substitution of ground granulated blast furnace slag shall be in accordance with 702.05. A water-reducing admixture or a water-reducing retarding admixture shall be used in the mix design, and the amount of water added shall be adjusted accordingly. The use of these admixtures shall be in accordance with 702.05.

90 When one of these alternate concrete mix designs are used in lieu of a concrete surface sealer, a finish in accordance with 702.21 will be required.

2020 INDOT Standard Specification

New Maintenance Programs..

- “Internal Sealing”-RCP
- 3% ADDITION Silica Fume
- 30% Slag Replacement
- Longer Service Life w/Reduced Maintenance
- Less Reliability of Maintaining Schedules



What Happened?



- Increased Cost
- Temperature Restrictions with Slag
- Slower Set Times with Slag
- Less Consistency
- No Sealing Required



Same Old, Same Old



Volatility!

Pop Outs from Bags or Non-Homogeneous Mixing



Shrinkage Cracking

“Stupid Burlap!”



- Additional Time & Resources
 - Cutting
 - Purchasing
 - Material Shortages
- Blamed for All the Problems
 - “Well....It’s Your Fault!”
- Contractor/INDOT Arguments
 - “Did you Cover Soon Enough?”
 - Did you Maintain a Proper Wet Cure
 - “This Finish is Horrible”
- Why is This STILL Happening!

“Enter Sandman”Well, Sort of..



What Can We Change?

- Curing...YES!
- Culture...YES!
- Good for the Concrete?

What Happened?

- Better Attitude
- Better Pumpability
- Better Finishability
- MORE Accountability & Closer Inspection

“Take a Memo!”



INDOT Issued First of Several Construction Memorandums

- Option to Use Nano Silica to;
 - Eliminate Wet Cure
 - Open Earlier Based on Strength
 - Utilize Curing Compound
 - Eliminate the Use of Evaporation Retarders

Can We Do More?

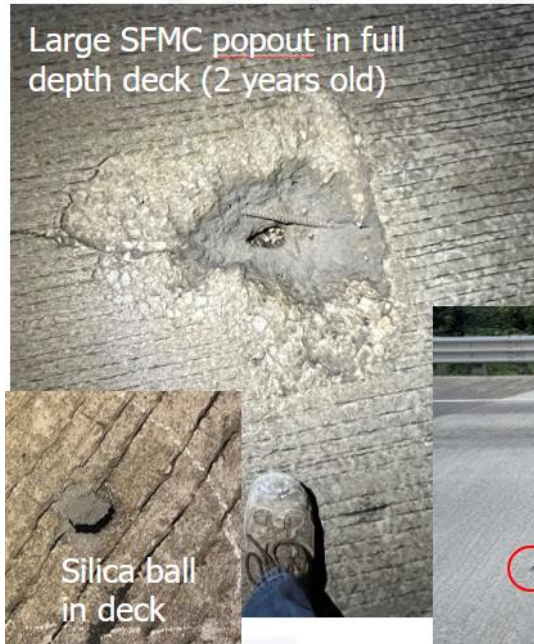
INDOT Class C Mix	Class C	Class C w/30% Slag Replacement	Class C w/3% Micro	Class C w/50 lb Micro (INDOT SFMC Overlay)	Class C w/20% Cement Reduction 1.25:1 Fly Ash	Class C w/1.8% LFA Replace
CEMENT	658	460.6	658	658	526	580
SLAG	0	197.4	0	0	0	0
FLY ASH	0	0	0	0	165	0
MICRO	0	0	19.4	50	0	0
W/C	0.42	0.42	0.42	0.42	0.42	0.47
WATER	276.36	276.36	284.508	297.36	290.22	272.6

The 580 Was Proposed To Ease Problems Specifically With Overlays!

*Proof is In the Pudding

*This is an expression, please don't eat the concrete

Overlays



E5 resolves mixing issues common with bagged silica fume

*Proof is In the Pudding

*This is an expression, please don't eat the concrete

9:03 1 LTE

← Search

Evaporation Calculator

Air	<- Temp ->	Concrete*
41		75
Wind		Humidity
16		74

Evaporation Rate:

0.302

[Calculate](#)

Unfavorable - Conditions exist where there is significant potential for plastic shrinkage cracking.

[Learn More](#)



I'm an Idiot!

*Proof is In the Pudding

*This is an expression, please don't eat the concrete

Protection shall be provided to prevent rapid drying of concrete. The rate of water evaporation shall be determined both prior to placement based on forecasted conditions and during placement based on actual conditions in accordance with ACI 308, section 5.2.1 or the following equation:

$$530 \quad E = (T_c^{2.5} - rT_a^{2.5})(1 + 0.4V) \times 10^{-6}$$

where:

E = Evaporation rate, lb/sq ft/h

T_c = Concrete mix temperature, °F

T_a = Ambient temperature, °F

r = (Percent of Relative Humidity)/100

V = Wind velocity, mph.

Measurement of T_a, r, and V shall be obtained from readings made by the local weather bureau or the Contractor's measurements made on site. Measurement of T_c shall be determined from the concrete on site at the point of placement. Fog misting shall be performed after the finishing operation and prior to the wet cure, where the evaporation rate exceeds or is expected to exceed 0.05 lb/sq ft/h. Fog misting shall keep the environment above the concrete surface at high humidity to protect against plastic shrinkage cracks and shall not be used to apply water directly to the surface to facilitate finishing. Evaporation retardants shall not be substituted for fog misting where the evaporation rate exceeds 0.05 lb/sq ft/h.

540

Nano Silica Benefits

- More Forgiving
 - Placement In Adverse Conditions
 - High Wind/Low Humidity
- Less Work
 - Increased Finishability
- More Efficient
 - Decreased Pump Pressures



Where Are They Now?

(The Secret's in The Sauce)

Concrete Mixes

- Used in Conjunction with Existing CMD
 - 3% Addition of Silica Fume
 - 30% Slag Replacements
 - Use 4 oz/cwt Internal Cure Nano Silica
- Use NEW Mix Option 2 For Existing Construction Memorandums
 - Reduce Cement to 550-650 lbs/cyd
 - Incorporate 4 oz/cwt Internal Cure Nano Silica
 - Incorporate 8 oz/cwt Liquid Fly Ash

Where Are They Now?

Original Usage:

- Bridge Decks
- Bridge Deck Overlays

Expanded Usage:

- Substructure Concrete
- Concrete Wall
- Slip Formed Concrete
- Full Depth Pavement
- Concrete Incidentals
 - Driveways
 - Curb & Sidewalk



Full-depth decks

- 202 pours (27-2020, 46-2021, 118-2022, 11-2023)
 - 2020/2021 – Curing compound only
 - 2022/2023 – Plastic sheeting only
 - 44 pours – E5-IC w/ 3% silica fume
 - 70 pours – E5-IC w/ 30% slag cement
 - 84 pours – E5-IC & E5-LFA (started in 2022)

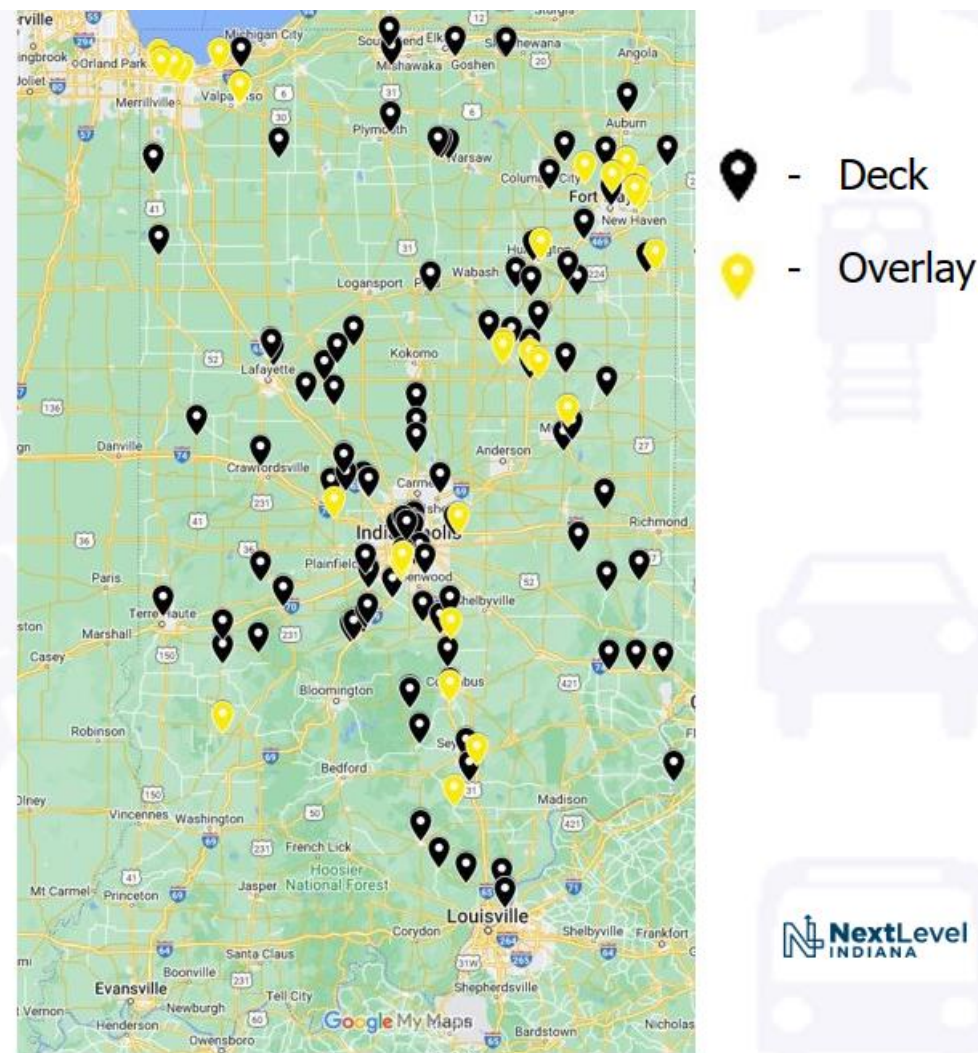
Deck Overlays

- 3 pours in 2020 (unsuccessful)
 - Added E5 IC to existing SFMC mix (658# cement)
- 44 pours (17-2021, 23-2022, 4-2023)
 - Traditional 7-day wet cure
 - E5-IC & E5-LFA & fiber (no bagged silica)

Paving (LFA only)

- 2 contracts (1 in 2021 & 1 in 2022)

All decks and overlays were contractor's option per construction memos 21-05, 22-02, 22-04 and 23-01



Easy Questions Only!!



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