INDOT's use of Colloidal Silicas
National Concrete Consortium - Spring 2022

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Nano-Silica

Silica Fume

- By-product of silicon chip manufacturing
- Pozzolanic - Reactive with calcium hydroxide (CH)
- Fine powder
  - (57 x more surface area than Portland cement/Fly Ash)

Nano-silica

- Manmade from salts and metals
- Pozzolanic - Reactive with calcium hydroxide (CH)
- Two forms
  - Very fine powder
    - (1714 x more surface area than Portland cement/Fly Ash)
  - Colloidal nano-silica

E5 Internal Cure and E5 Liquid Fly Ash

- Developed by Specification Products (Noblesville, IN)
- Colloidal silica (modified)
- Patented
  - Batch sequencing is critical
  - Particle composition and size range are unique
- "Internal Curing" and "Fly Ash" ??
  - Cement grains electrically bond more molecules of water due to tiny particle size
  - More efficient hydration of cement particles

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E5 Internal Cure and E5 Liquid Fly Ash

Full-depth decks

- 77 pours (26 in 2020, 41 in 2021, 10 in 2022)
  - Added E5 IC to existing mixes w/ curing compound only
  - Memo 21-05 (optional - zero cost change order)
- 12 pours with 580# cement w/ E5 IC and LFA only

Overlays

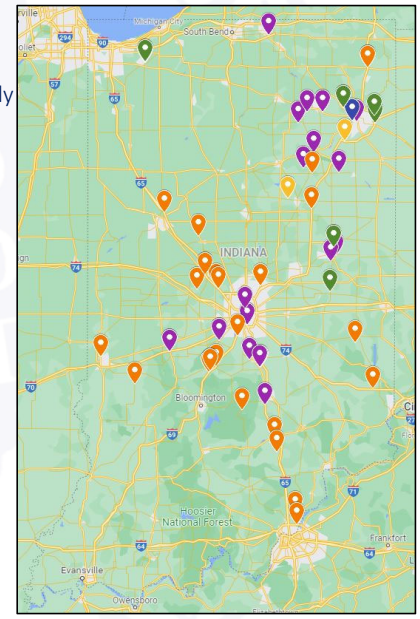
- 3 pours in 2020 (unsuccessful)
  - Added E5 IC to existing SFMC mix (658# cement)
- 19 pours in 2021
  - 600# cement w/E5 and LFA & fiber(no bagged silica)
  - Traditional 7-day wet cure

Paving

- 1 in 2021 (LFA only)

Broad participation

- 11 different contractors
- 6 different ready-mix companies
- Allen & Whitley Counties
- Purdue University, West Lafayette IN



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E5 Internal Cure and E5 Liquid Fly Ash

Benefits

Placement

- Improved workability
- No water applied on the surface
- Longer window for finishing
- Minimal bleed rate
- Eliminate evaporative retardants (90% water)
- Consistent air entrainment
- Lower pump pressure
- No wet curing (curing compound or plastic)

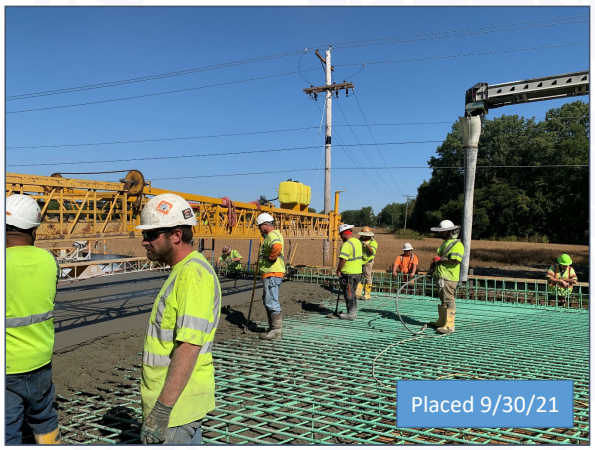
Hardened concrete

- Pozzolanic (more nucleation sites)
- Cement/paste reduction
- Improved strength
- Minimal to zero cracking
- Reduced permeability
- Reduced CH & Ca-Oxy (report coming)
- Hardened air ??

INDOT's original goal:
Resolve issues behind the screed

E5 Internal Curing Admixture and Liquid Fly Ash

More forgiving



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26" thick reinforced slab deck - 580# cement, 4 oz/cwt E5 & 8 oz/cwt LFA

E5 Internal Curing Admixture and Liquid Fly Ash

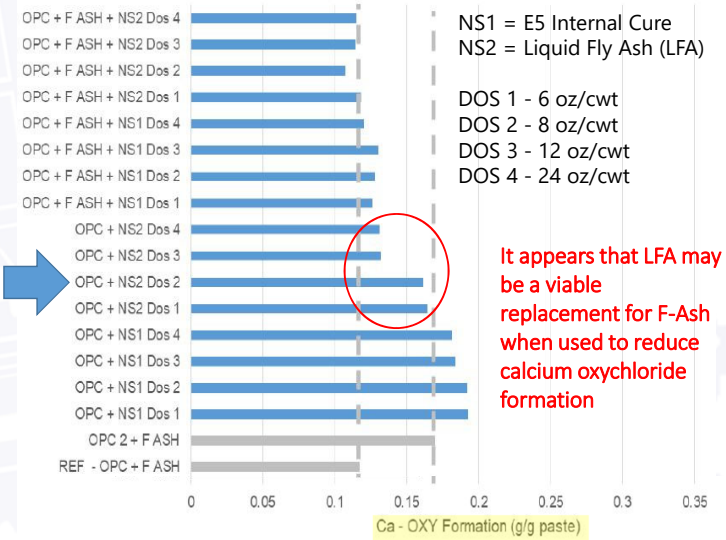
Overlays

Mix design

- Cement content 600 pcy
- 4 oz/cwt E5 Plus Internal Cure admixture
- 8 oz/cwt E5 Liquid Fly Ash (LFA) admixture
- Fibrillated microfiber
- 0.46 W/C ratio (minimum)
- Traditional water cure & machine grooving

E5 Liquid Fly Ash

Pavement



NS1 = E5 Internal Cure
NS2 = Liquid Fly Ash (LFA)

DOS 1 - 6 oz/cwt
DOS 2 - 8 oz/cwt
DOS 3 - 12 oz/cwt
DOS 4 - 24 oz/cwt

It appears that LFA may be a viable replacement for F-Ash when used to reduce calcium oxychloride formation

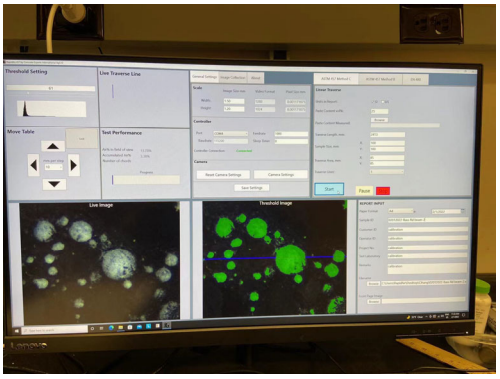
Source: Dr. J. Weiss J. & Dr. Belkowitz 2021

Rapid Air- Air Content

	Test 1	Test 2	Test 3	Average	
Bass Rd Sample	7.77%	9.31%	7.99%	8.36%	Cores
Lab prepared reference	10.48%	10.77%	10.14%	10.46%	Cylinders

- According to the Rapid Air result, the Bass Rd sample exhibited a lower air content, compared with reference sample;
- The 8.36% of air void in the Bass Rd sample meet the INDOT requirement to resist the freeze-thaw damage.

--- INDOT 501.05 Concrete Mix Criteria



Source: Dr. Luna Lu, Purdue University 2022 & Specification Products, Noblesville IN

Water Sorptivity Test

	Initial absorption 10^{-3} mm/s$^{0.5}$	Secondary absorption 10^{-3} mm/s$^{0.5}$	
Bass Rd Sample	6.8 (1.2)	1.7 (0.5)	Cores
Lab prepared reference	10.7 (0.28)	1.5 (0.06)	Cylinders

- An overall reduction of the absorption rate indicates a denser cement matrix, with a lower void content.

Source: Dr. Luna Lu, Purdue University 2022 & Specification Products, Noblesville IN

Compressive Strength

	Sample #1	Sample #2	Sample #3	Average	
Bass Rd Sample (135 d)	8403 psi	7004 psi	6019 psi	7152 psi (1198)	Cores
Lab prepared reference (28 d)	5481 psi	5640 psi	5713 psi	5611 psi (118)	Cylinders

- The compressive test was conducted at the age of 135 day.

Source: Dr. Luna Lu, Purdue University 2022 & Specification Products, Noblesville IN

E5 Internal Curing Admixture and Liquid Fly Ash

Key points

Traditional flexural/compressive strength relationship is changed
- Improved bonding between aggregate and paste
- Improved bonding between paste and substrates

Needs more water
- Increased efficiency of cement hydration
- Increased surface area

Reduce cement
- Ready mix 560 – 600 Lbs/Cyd
- Slip form PCCP ??
- Type 1L ??

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Thank You !

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Questions