Practical Implementation of Superabsorbent Polymers for Internally Cured Concrete

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Outline

- Research overview
  - Introduction
  - Previous Research
  - Goal & Objectives
  - Experimental Summary
- Methodology
  - Materials
  - Methods
  - Concrete Mix Design
- Results and Discussions
  - Workability (Slump) and Air Content
  - Strength Characteristics (Flexural and Compressive Strength)
  - Thermocouple Temperature Analysis
- Future Works
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MOTIVATION

The use of durable concrete is a promising strategy to mitigate the global impact of concrete production and utilization on the environment.

Durability

Service Life

- ❖ **Internal curing.**
- ✓ Higher degrees of hydration,
- ✓ Reduce shrinkage and cracking potentials [1].

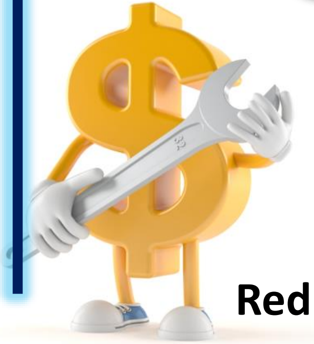
This is achieved through **water entrainment** procedures to create **reservoirs** in concrete

Durable concrete usage helps to:

Decrease CO_2 emissions and energy consumption

Decrease frequency of replacement of existing structures

Increase return on investment



Reduce maintenance costs

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Dry SAP

Wet SAP

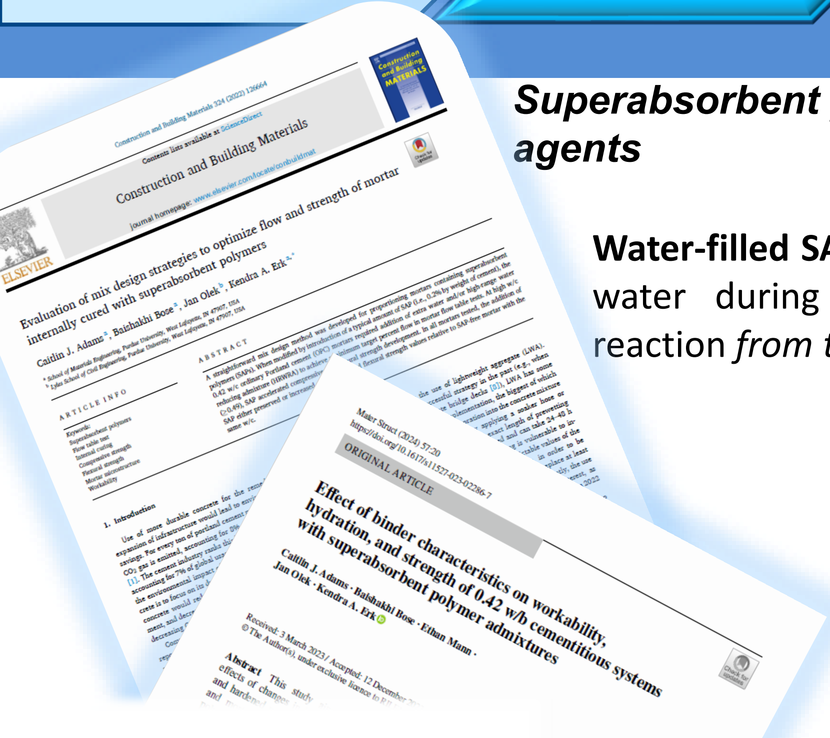
Superabsorbent polymers (SAPs) popularly known as **hydrogels**, are cross-linked polymers with capability of absorbing large volume of fluid in comparison to its own mass, forming insoluble gel [2].

They act as;

- ✓ **Internal water reservoirs**
- ✓ Alternative to lightweight aggregates (LWA) for **internal curing** purposes.

Benefits:

- ✓ **Improve hydration**
- ✓ **Reduce moisture gradient**
- Mitigate **durability** challenges in cementitious systems
  - Drying and autogenous shrinkage,
  - Scaling resistance (by improving strength and minimizing near-surface drying)
  - Improve quality of microstructure (chloride permeability, etc.)

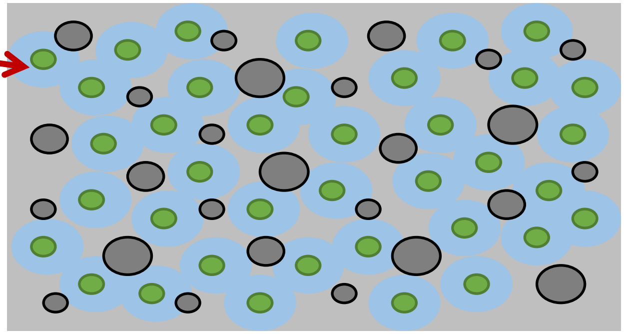


Superabsorbent polymers (SAPs) as internal curing agents

Water-filled SAP particles ("hydrogels") release water during curing to fuel the hydration reaction *from the inside*.

Output

- ✓ Absorption capacity of SAP in cement mortar
- ✓ When in the mixing sequence should SAP be added
- ✓ Is extra water required to maintain workability of mortar using SAP.
- ✓ Effect of extra water on mechanical properties of SAP mortar [5].



- ❖ Comparable or improved mechanical properties
- ❖ Reduces autogenous shrinkage
- ❖ Improves hydrations [1]
- ❖ Increases durability [6],[7]

Adams, C. J., Bose, B., Mann, E., Erk, K. A., Behnood, A., Castillo, A., Rodriguez, F. B., Wang, Y., & Olek, J. (2022). *Superabsorbent polymers for internally cured concrete* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2022/04). West Lafayette, IN: Purdue University. https://doi.org/10.5703/1288284317366

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Project Goal

To determine how **delivery method** and **mixture composition** influence performance of internally cured concrete mixtures containing a commercial SAP formulation and **Type IL cement** with SCMs such as **slag**, and **nanosilica.**

Research Objectives

1. Evaluate the **internal curing performance** of commercial SAP in concrete mixtures containing Type IL cement as well as SCMs including slag, and nanosilica.

2. Develop and evaluate practical field **implementation strategies** to successfully deliver and disperse SAP in concrete mixtures.

3. Conduct field trials to compare the **strength** and **durability** of SAP-containing mixtures with externally cured concrete.

Packaged SAP particles

Approx. 1 lb. of dry SAP is needed for 1 cu. yd. class C concrete (**0.2% SAP by weight of binder**)

Dissolvable bag enclosed in an outer, **water-proof plastic bag** *(outer bag removed before the dissolvable bag introduced to the mixer)*

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Slabs

Prisms

Beams

Cylinders

Application of curing compound

Thermocouples installed in slabs and cylinders connected to Data logger

Cores from the slabs retrieved at age of 7, 28, 56 and 90 days

Cement
Ordinary Portland Cement – Type 1L

Fine Aggregates
(4.75mm – 75µm)

Admixtures

Superabsorbent polymer
Polyacrylamide-based particles
dry diameter < **300 µm**

Slag Cement
Grade 100

Coarse Aggregate
(25 mm – 2.36 mm)

Potable Water

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Flexural Strength Testing
ASTM C78

Thermogravimetric Analysis
ASTM E1131

Rate of Water Absorption
ASTM C1585

Isothermal Calorimetry
ASTM C1679

Compressive Strength Testing
ASTM C39

Electrical Resistivity Testing
AASHTO TP 119

Target Slump (inches)	3 – 7
Target Air Content (%)	5 – 8

Summary of CMDs (Slabs 6 – 11)

Mix	Cement (lb./cuyd)	Slag (by weight of cement)	w/cm	Nano silica IC	SAP (bags/cy)	FA/tot. agg	WRA (fl. oz/ 100 lbs. of cementitious)	AEA (fl. oz/ 100 lbs. of cementitious)
Slab 6 (Reference)	658		0.44			0.41	–	~ 0.9
Slab 7 (Ref + Nano silica IC)	658		0.44	4 oz/cwt		0.41	–	~ 0.8
Slab 8 (Ref + Slag)	461	197	0.44			0.41	–	~ 0.8
Slab 9 (Ref + Slag + Nano silica IC)	461	197	0.44	4 oz/cwt		0.41	_	~ 0.8
Slab 10 (Ref + SAP)	658		0.44		1 bag	0.41	–	~ 0.8
Slab 11 (Ref + SAP+ Slag)	461	197	0.44		1 bag	0.41	–	~ 0.9

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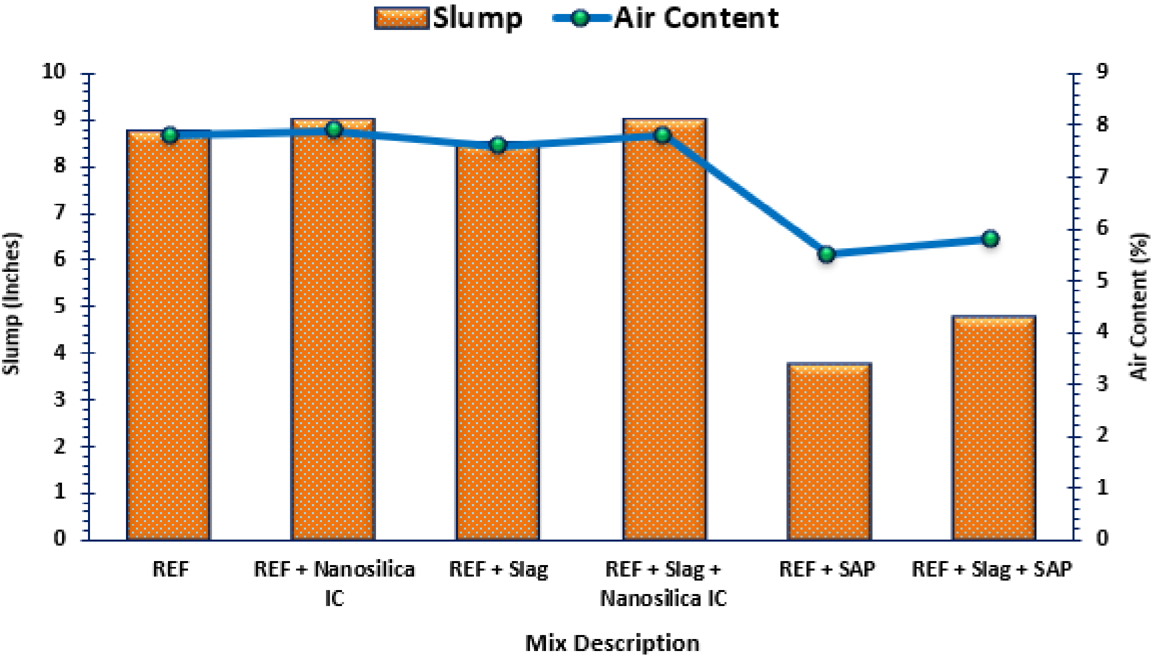
Slab Description	Slump (inches)	Air Void (%)	Unit Weight (lb)
Reference	8.75	7.80	34.30
REF + Nanosilica IC	9.00	7.90	34.39
REF + Slag	8.50	7.60	34.53
REF + Slag + Nanosilica IC	9.00	7.80	34.52
REF + SAP	3.75	5.50	35.61
REF + SAP + Slag	4.88	5.80	35.42



Target Air Content (%) = 5 – 8

Target Slump (inches) = 3 – 7

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REF

REF + SAP

REF + Slag +SAP

Air Content (%) = 7.80
Slump (inches) = 8.75

Air Content (%) = 5.50
Slump (inches) = 3.75

Air Content (%) = 5.80
Slump (inches) = 4.88

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Field Acceptance Properties:

Minimum water/cementitious ratio .... 0.320[B]
Maximum water/cementitious ratio .... 0.450[B]
Slump, formed .... 2 to 6 in.
Slump, slipformed .... 1.25 to 3 in.
Air Content .... 5.0% to 8.0%
Minimum modulus of rupture .... 570 psi at 7 days[C]
Relative Yield .... 0.98 to 1.02

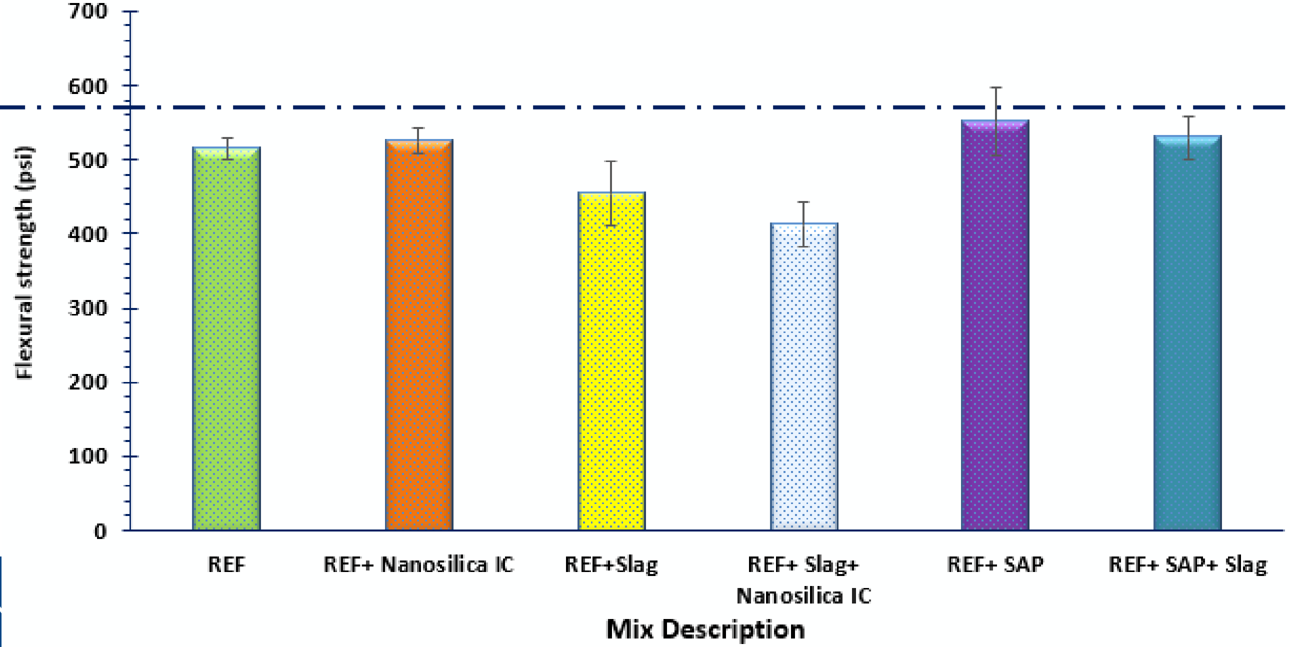
[A] The target cement content during production shall not be adjusted from the value stated on the CMDP.

[B] The water cementitious ratio during production shall not deviate more than 0.020 from the target stated in the CMDP and shall not fall outside the limits above.

[C] Beams shall be standard cured in a water tank in accordance with AASHTO T 23 and 505.01(a). The water does not need to be saturated with calcium hydroxide. Minimum flexural strength for opening to traffic shall be in accordance with 506.12.

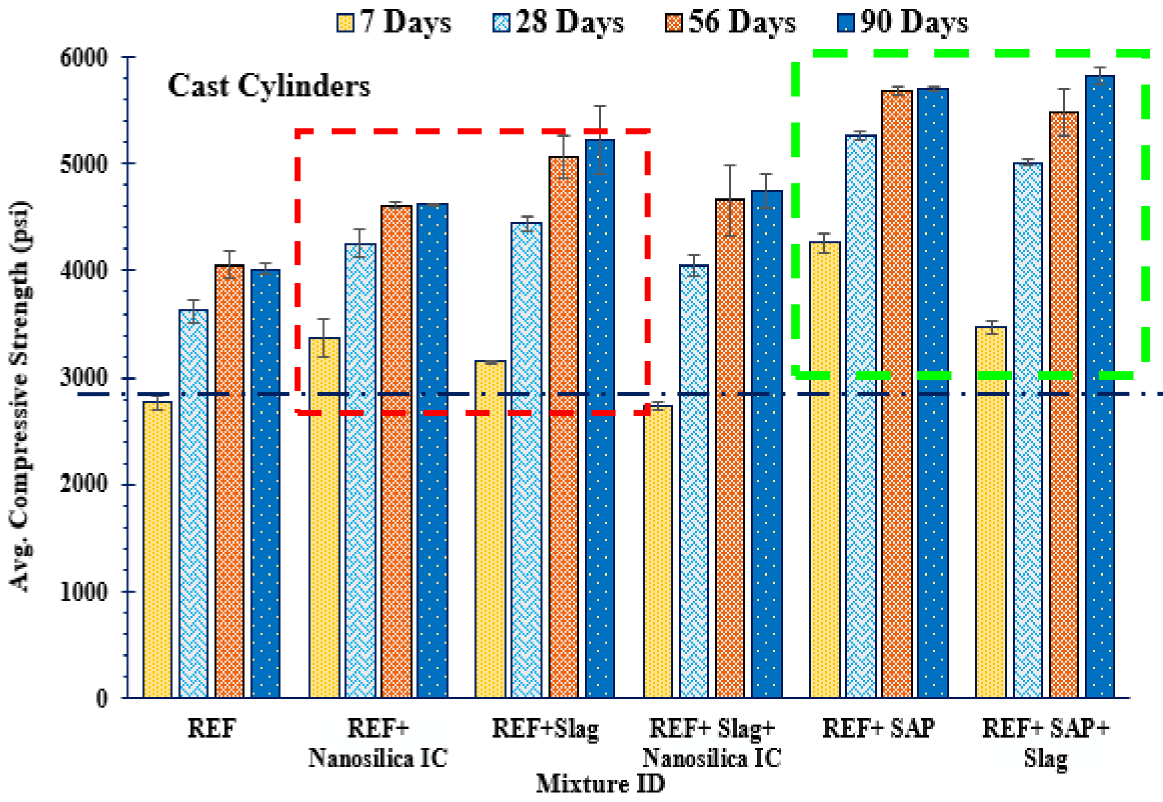
Slab No.	Description	w/b	Flexural Strength at 4 Days	
			psi	MPa
6	REF	0.44	515.13	3.55
7	REF+ Nanosilica IC	0.44	524.96	3.62
8	REF + Slag	0.44	454.21	3.13
9	REF+ Slag+ Nanosilica IC	0.44	411.79	2.84
10	REF+ SAP	0.44	550.63	3.79
11	REF+ SAP+ Slag	0.44	530.33	3.65

- Flexural strength at 4 days, ~ 412 – 551 psi.
- Achieved the minimum specified standard at 7 days by 3 days earlier.

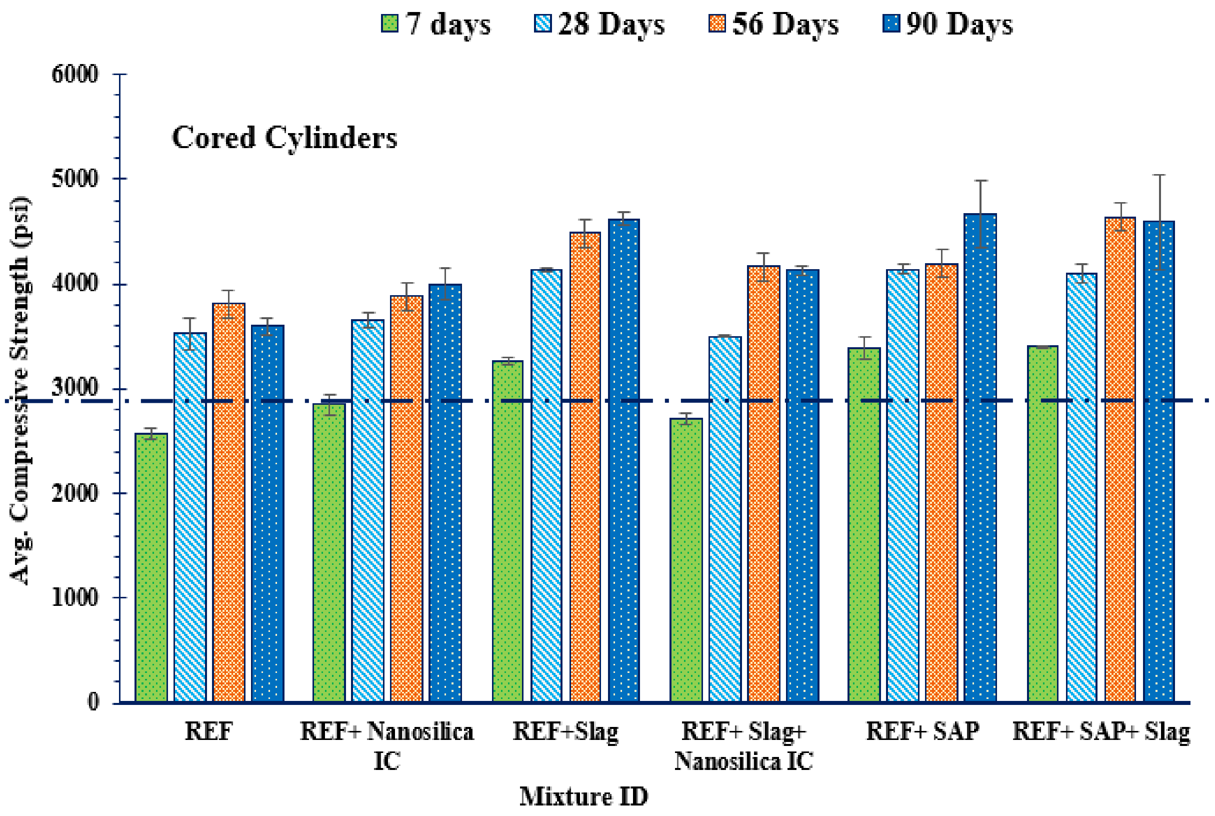


INDOT. (2024). 2024 Standard Specifications. Retrieved from INDOT website

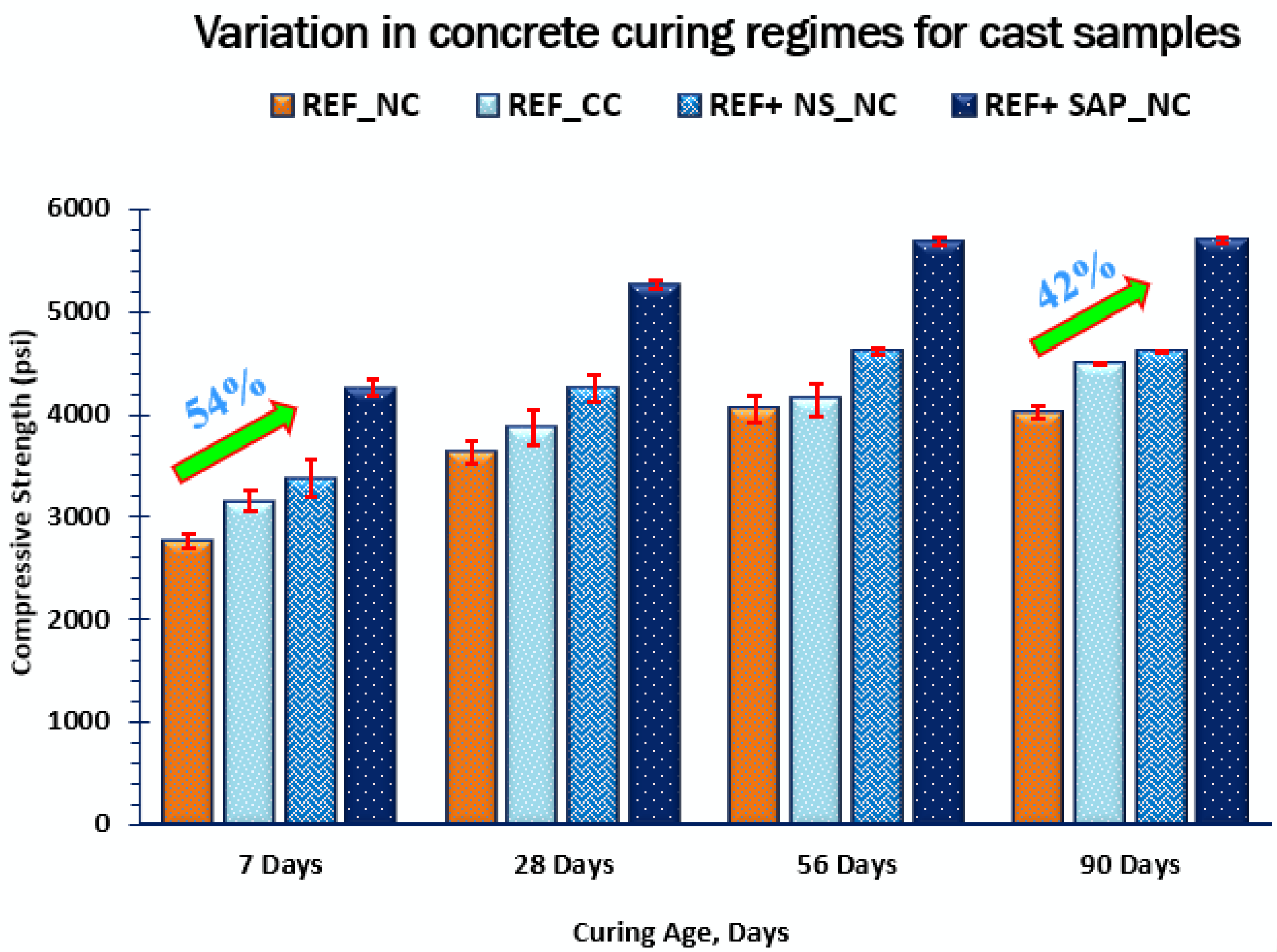
Compressive strength for cast samples with age



Compressive strength for cored samples with age



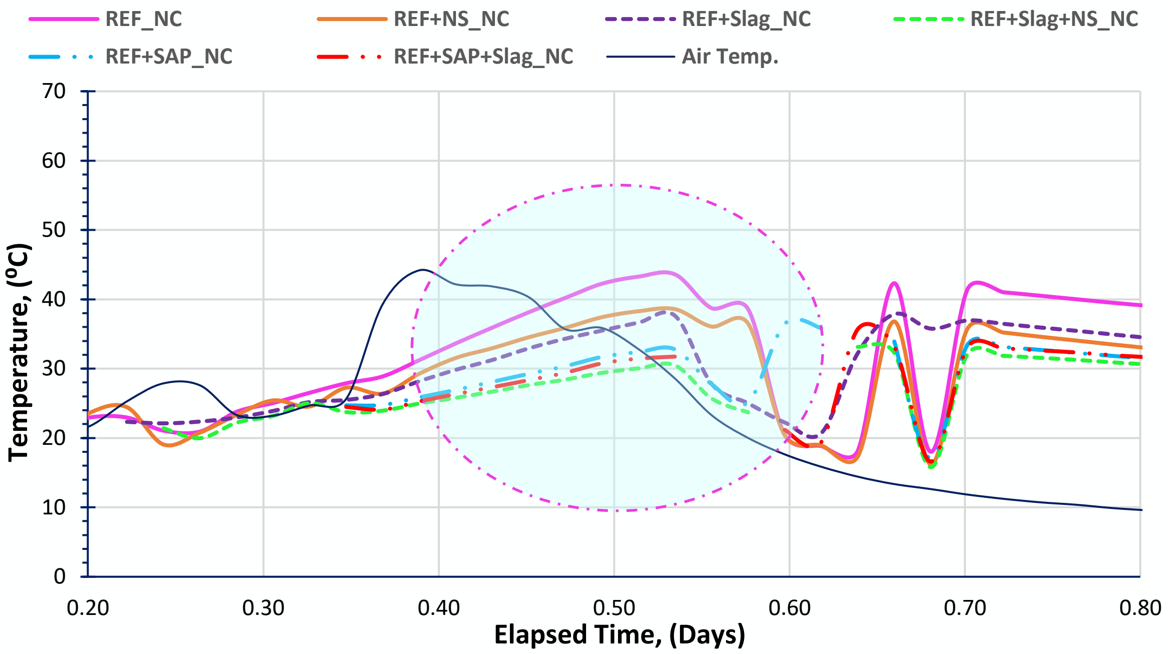
Curing Condition	Designation
No Curing Compound	NC
Curing Compound	CC



Highpoints

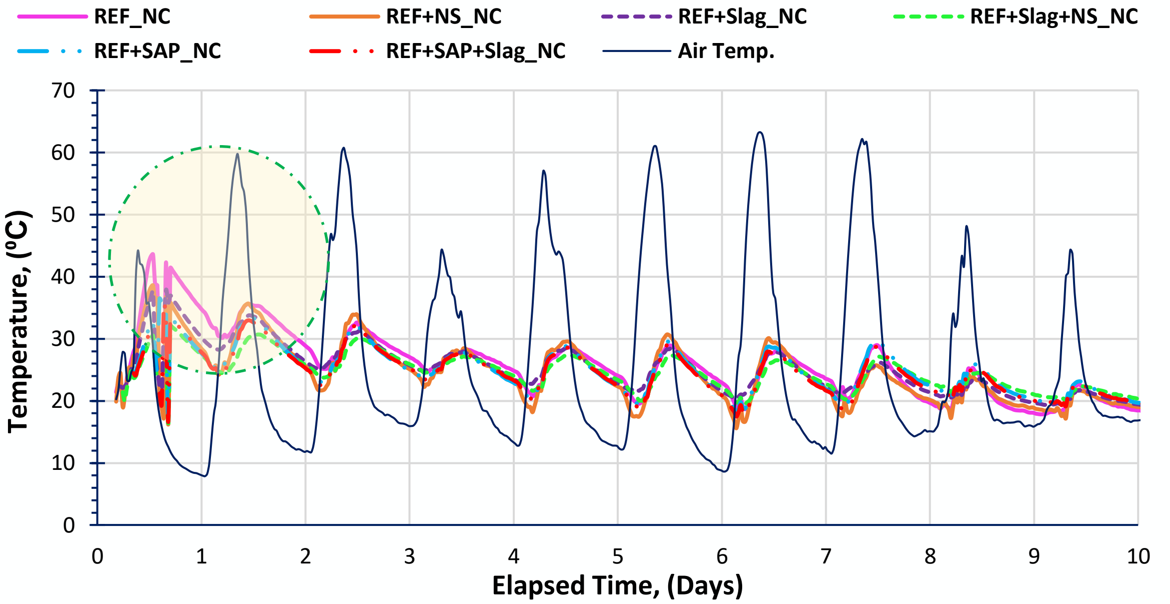
- The application of the curing compound improved the strength by **14%, 7%, 2%** and **12%** for the 7, 28, 56, 90 days respectively.
- Addition of SAP improved the strength by **54%, 45%, 40%** and **42%** for the 7, 28, 56, 90 days respectively.

Description	Peak Temp. (^{0}C)	Time to Peak Temp. (Hrs.)	Air Temp. at Peak (^{0}C)
REF	43.59	8.30	28.56
REF + NS	38.58	8.30	28.56
REF + Slag	37.86	10.30	13.35
REF + Slag + NS	33.14	9.30	14.42
REF + SAP	36.45	6.00	17.64
REF + SAP + Slag	35.69	7.00	14.42

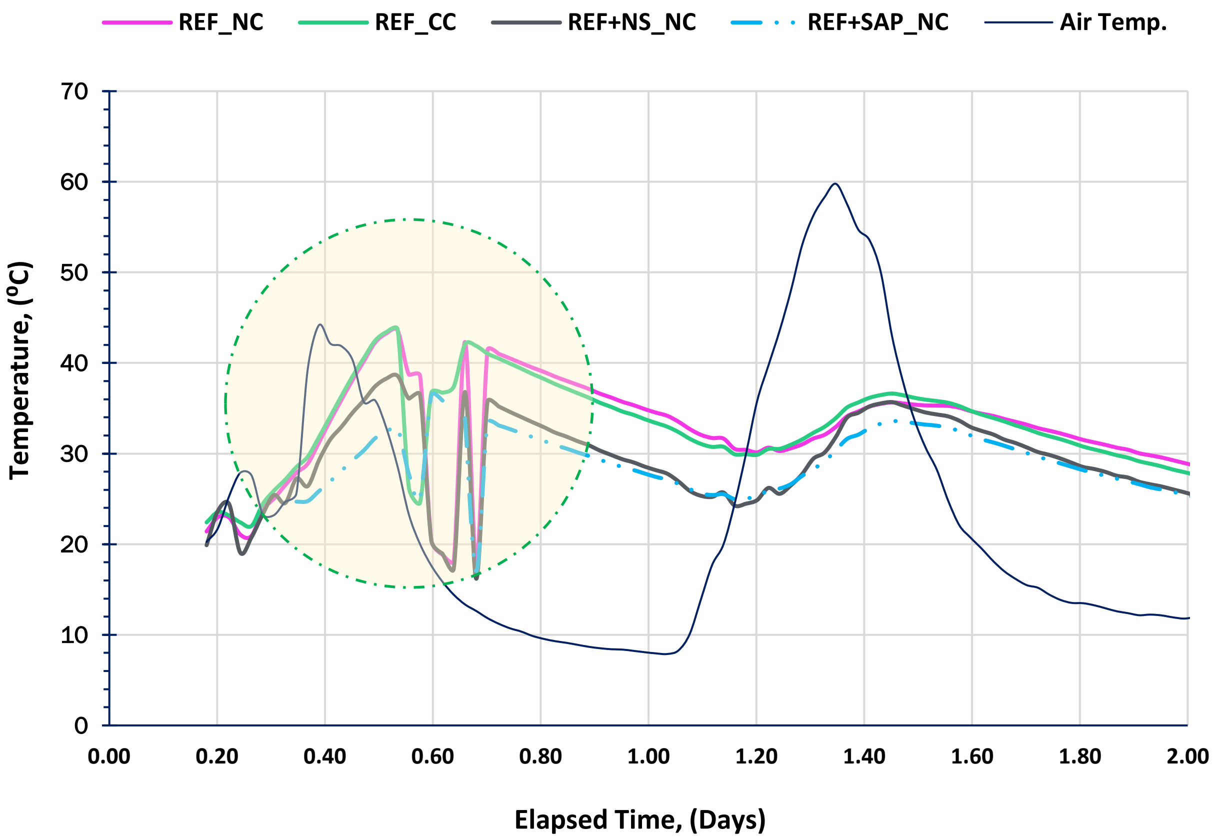


Highpoints

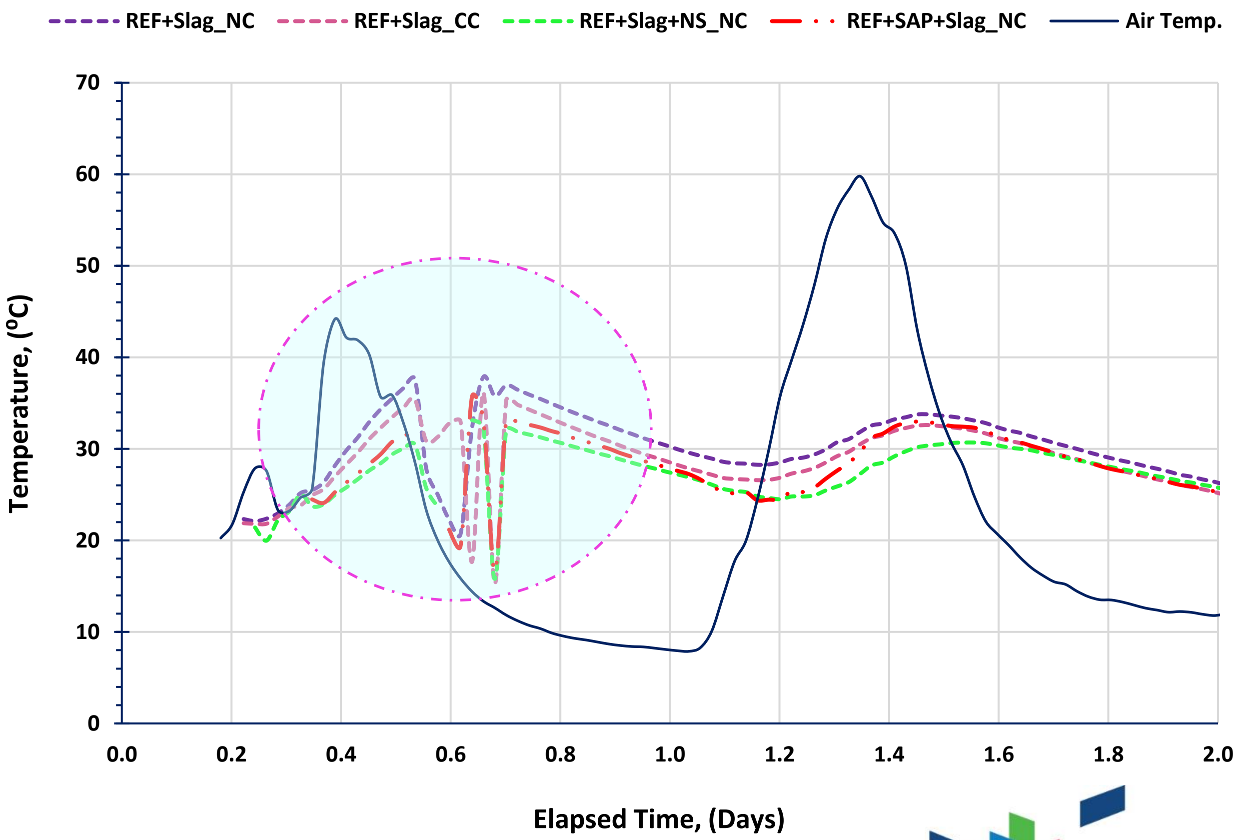
- Addition of nanosilica, **decreased** the slab core temperatures by **13%,** but the time to reach peak temperature remained **unchanged.**
- Replacement of cement with 30% slag **decreased** the slab core temperature by **13%**, but it **extended** the time to reach peak temperature by 2 hrs. (~10 hrs.)
- Addition of SAP **decreased** the slab core temperature by **16%**, and **decreased** the time required to attain peak temperature by 2 hrs. (~6 hrs.).



Variation in heat generated with different curing regime



Variation in heat generated with SCM under different curing regime



In summary, having performed the field trials on the practical implementation of superabsorbent polymers for internally cured concrete, the following remarks have been drawn:

- Concrete mixtures with 0.2% cwt of SAP exhibited **enhanced performance** attributed to **improved hydration** due to **internal curing,** especially when comparing mixtures subjected to different curing regimes.

- The **reduction in workability** and concurrent **improvement in strength** observed in concrete mixtures upon the addition of superabsorbent polymers particles validate the **efficacy of delivering SAP via dissolvable bags**.

- The replacement of cement with 30% slag **decreased** the slab core temperature by **13%**, but it **extended** the time to reach peak temperature by 2 hrs. (~10 hrs.).

- Addition of SAP particles **decreased** the slab core temperature of by **16%**, and **decreased** the time required to attain peak temperature by 2 hrs. (~6 hrs.).

- Concrete mixtures incorporating SAP particle and cement replacement with 30% slag showed **improved performance** in comparison with the concrete mixture with only SAP particle. This indicates **greater compatibility** of SAP particles, supplementary cementitious material and Type 1L cement.

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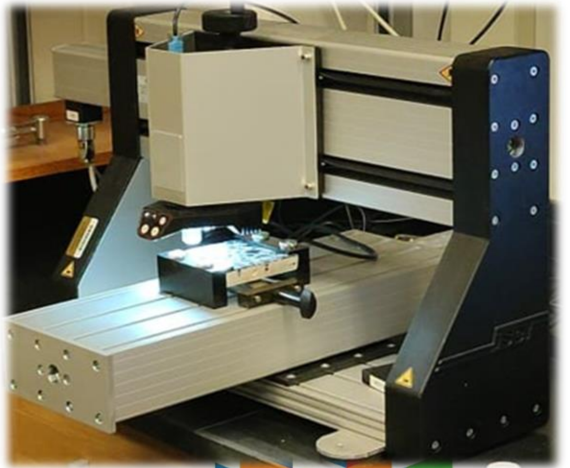
The future work will involve experiments evaluating the durability performance of the field samples.

- **Scaling Resistance:** Exposure of the concrete samples to deicer salts and monitored over 50 cycles.
- **Thermogravimetric Analysis**: Evaluate CH content by thermogravimetric analysis.
- **Drying Shrinkage:** 3 in. x 3 in. x 12 in. prismatic specimens are monitored for drying shrinkage.
- **Microstructure Evaluation:** using SEM imaging.
- **Air Void Analysis:** using the Rapid Air evaluation technique.
- **Chloride diffusion coefficient:** Estimation of acid soluble chloride profile using automatic titrator.



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Thank You

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