FY22 FECM Spring R&D Project Review Meeting
Project Update - DE-FE0031931

Facilitating Implementation of High-Volume Fly Ash Use in Precast Concrete Construction to Increase Beneficial Utilization

Matthew J. Gombeda, PhD (PI)

Assistant Professor of Civil Engineering
Department of Civil, Architectural and Environmental Engineering
Illinois Institute of Technology
Chicago, IL

ILLINOIS INSTITUTE OF TECHNOLOGY
Armour College of Engineering

PennState

LEHIGH UNIVERSITY

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Project **Background** and **Motivation**

Fly ash (FA), a coal combustion residual (CCR), is one of the most commonly used supplementary cementitious materials (SCMs).

FA particles carried out of coal combustion chamber by exhaust gases and subsequently filtered out

Two main classifications:
Class F → FA w/ pozzolan properties
Class C → FA w/ pozzolan & **cementitious** properties

Often used as a [partial] replacement of conventional Portland cement
→ With restrictions in precast construction

FA use is more widespread in cast-in-place (CIP) concrete construction than **precast** concrete due to stringent **structural performance requirements**.

Development of **high early strength** is crucial for precast components

Maximizes operational efficiency of the facility by turning over casting beds rapidly

Components often stripped from formwork within ~24 hours of fresh concrete placement

Second photo source: "QUIKLIFT™ DTA Installation to Stripping (Precast Double Tee) by ALP Supply (formerly Patterson)" https://www.youtube.com/watch?v=sBCznhGwfFY&ab_channel=ALPSupply

Project **Objectives** and Expected **Outcomes**

1) Increase fly ash beneficial use by at least 15% in the precast concrete industry

2) Maintain or exceed stringent structural property requirements
   (e.g., compressive strength at initial prestress, modulus of rupture, etc.)
   Ex: 3500 psi compressive strength typical at initial prestress (~24 hrs.)

3) Exhibit little or no additional cost relative to conventional mixtures

4) Mitigate detrimental environmental consequences inadvertently caused by increased beneficial use

5) Facilitate diversion and harvesting of large fly ash quantities from landfills or impoundments

6) New design guidelines and code provisions for sustainability requirements for concrete mix designs

Project **Tasks**

Task 2 - Assessment of the state-of-the-art practices and initial materials procurement

Task 3 - Material formulation development

Task 4 - Performance testing of concrete mixtures

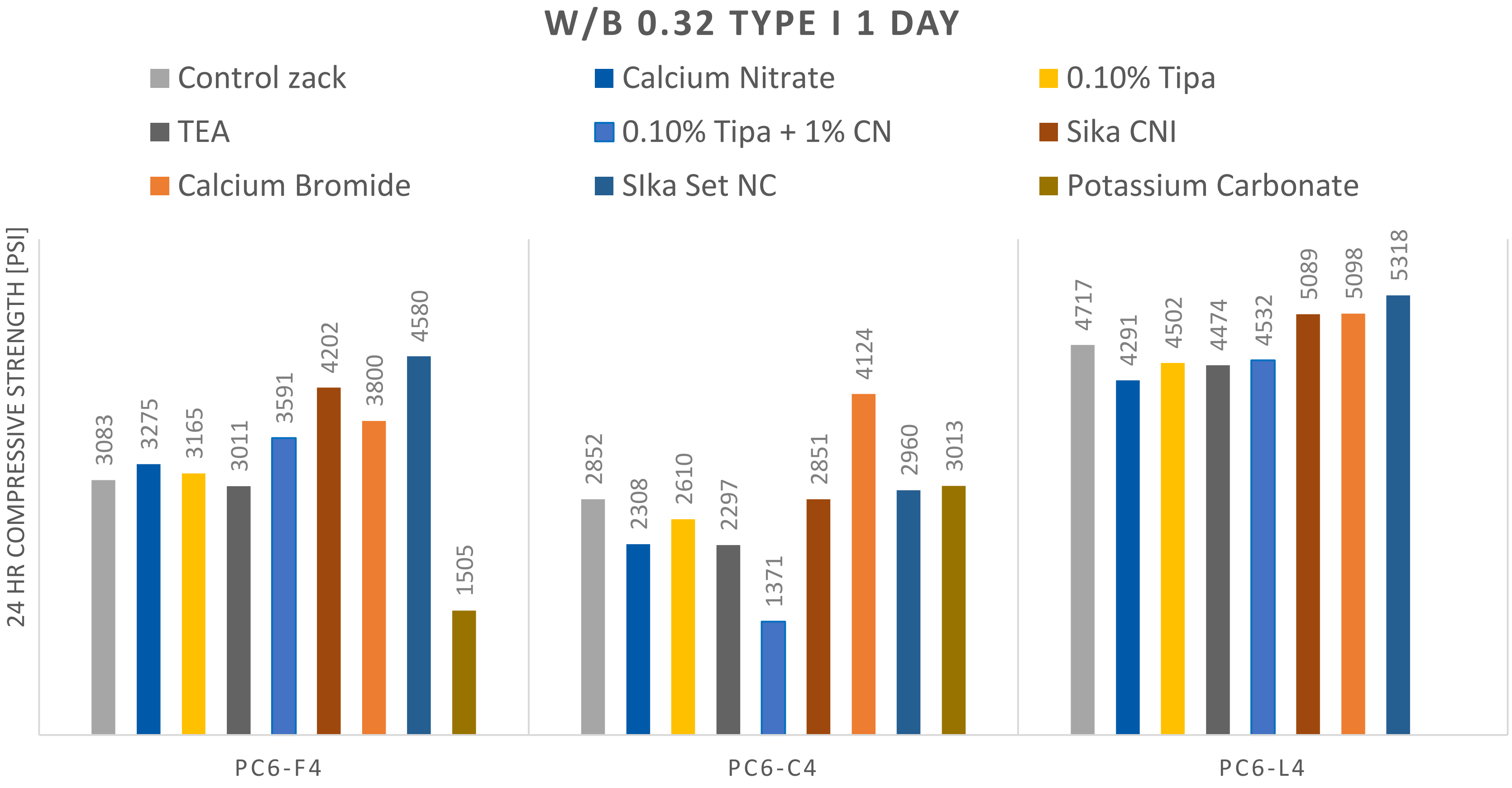
Task 5 - Design, fabrication, and experimental testing of full-scale specimens

Task 6 - Environmental impact study and life cycle assessments

Progress to Date

Evaluation of HVFA ***[binary]*** **binders** (Task 3)

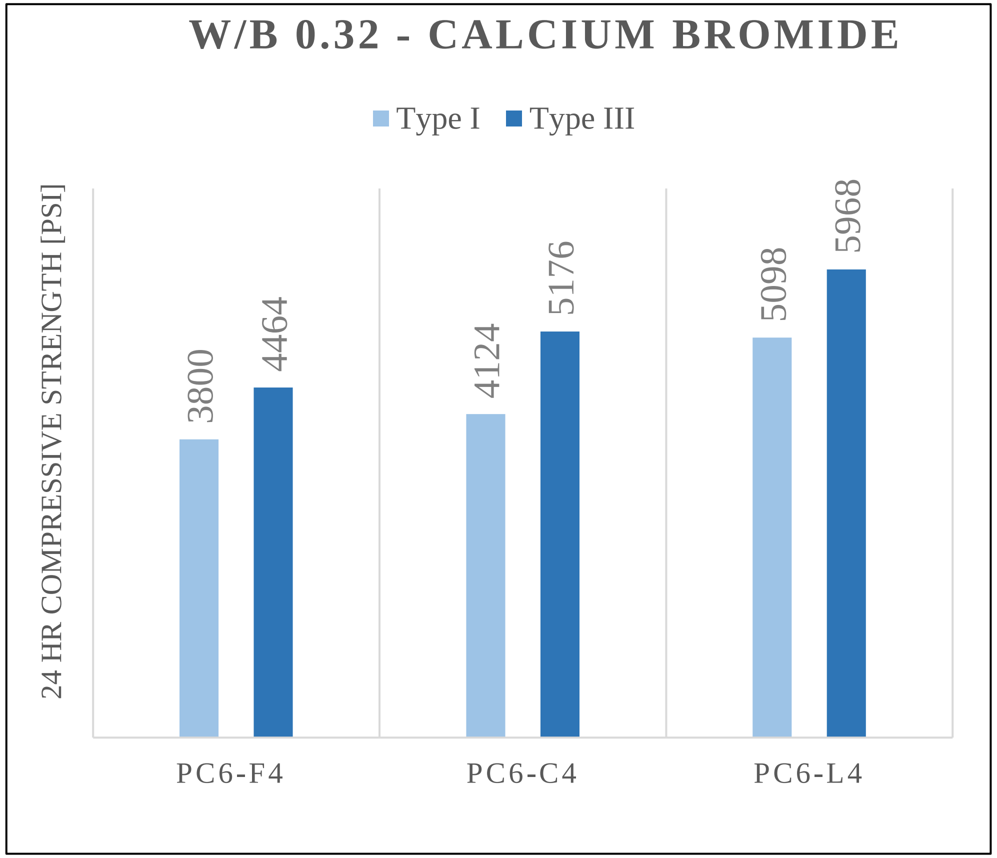
- → **GOAL:** ~4000 psi compressive strength of mortar samples at 24 hrs.
- → <u>NOTE</u>: Slightly different than the overall goal of 3500 psi for concrete (discrepancy between mortar and concrete)

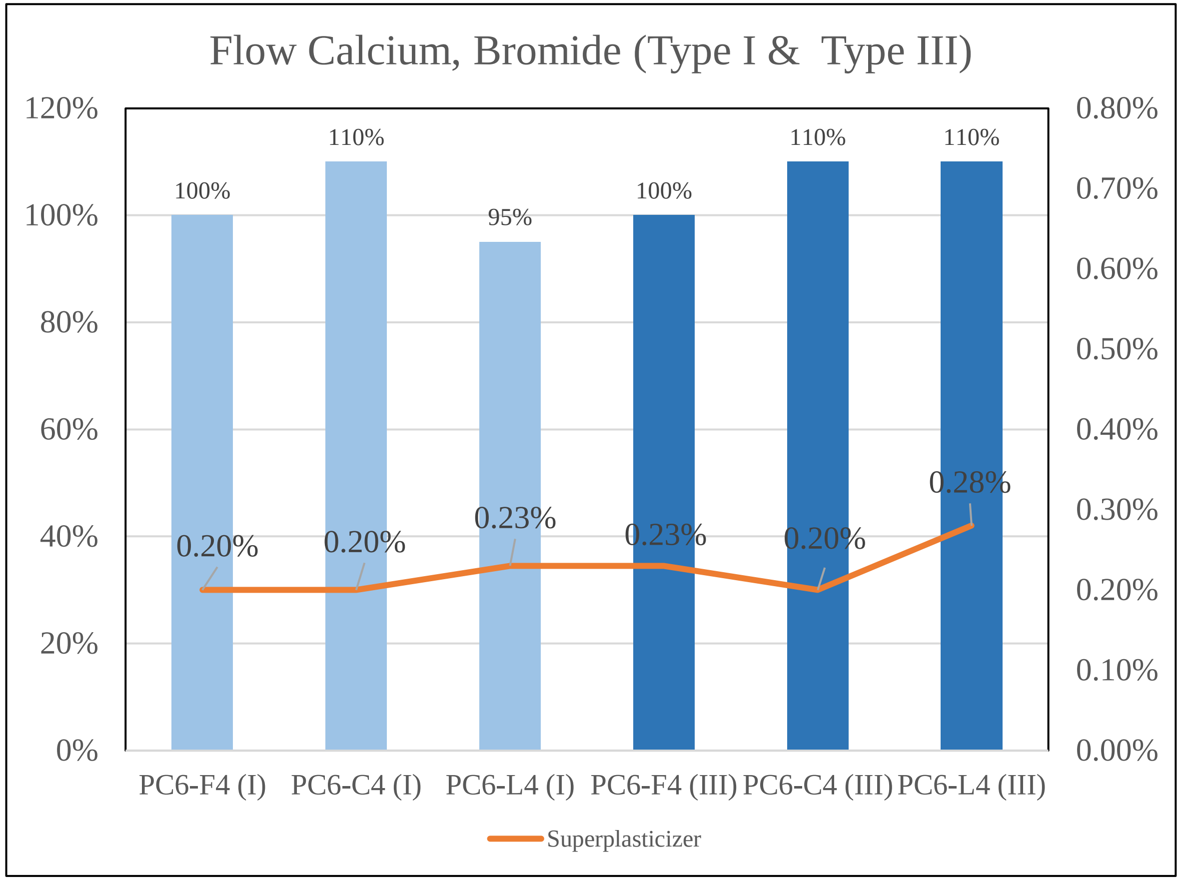


40% Fly ash, 60% Portland Cement Type I

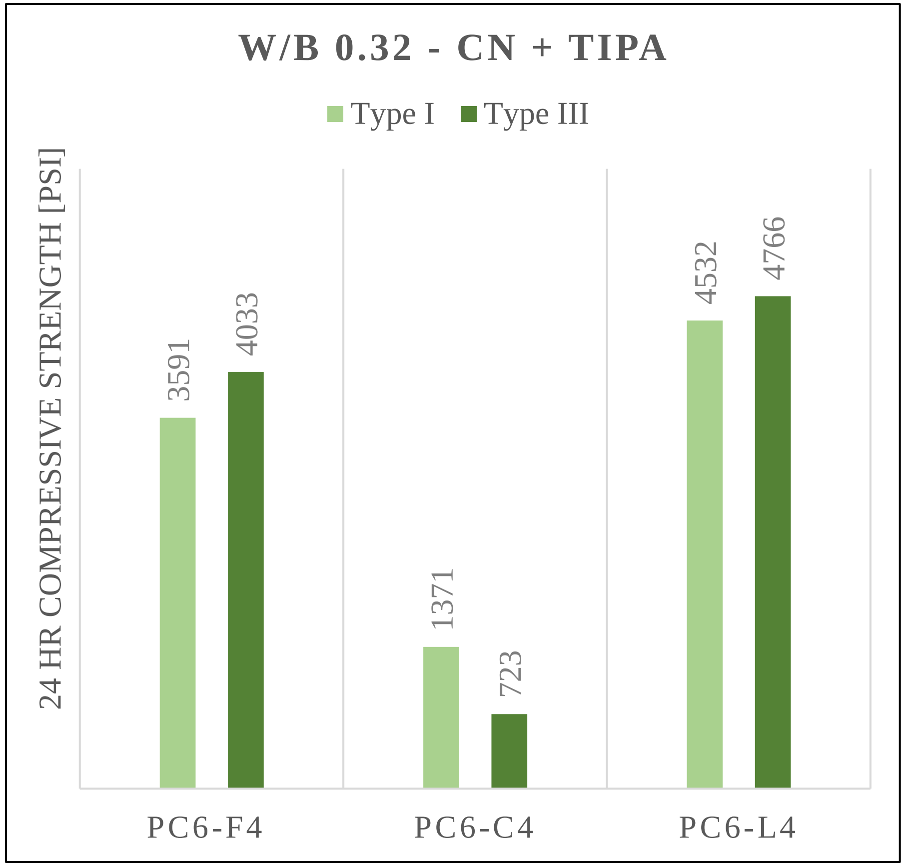
<u>Successful Accelerators:</u>
1- Calcium Bromide
2- Tipa (Triisopropanolamine) + CN (Calcium nitrate)
3- Sika Set NC (Calcium Nitrate, Sodium Thiocyanate)
4- Sika CNI (Calcium Nitrite)

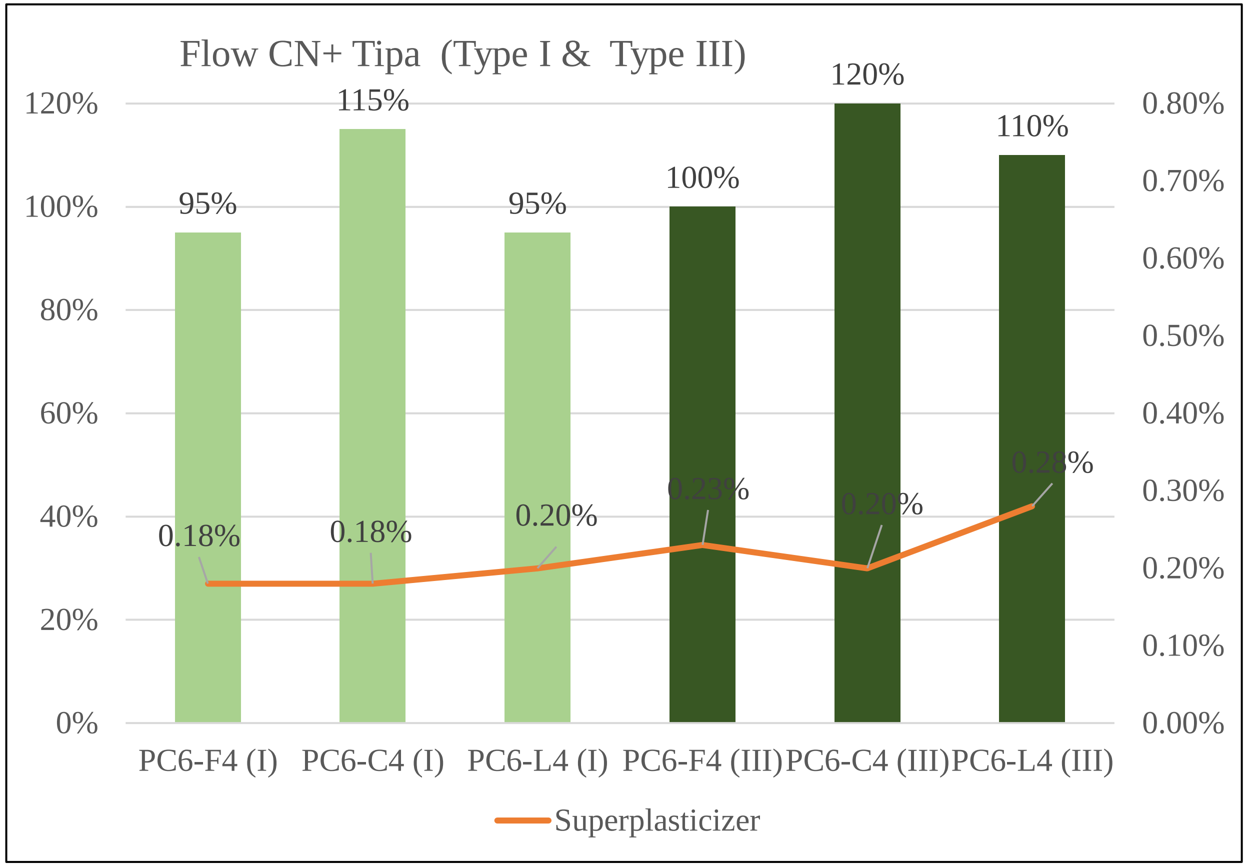
Evaluation of HVFA ***[binary]* binders** (Task 3) cont…



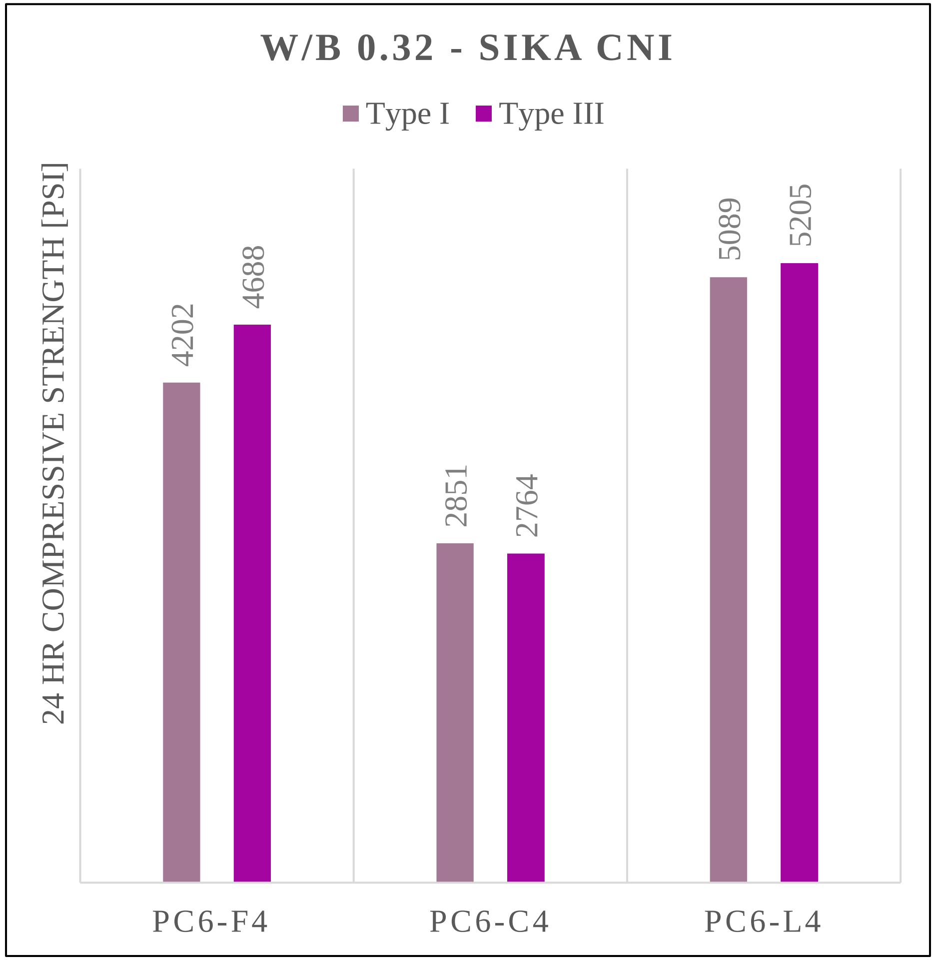


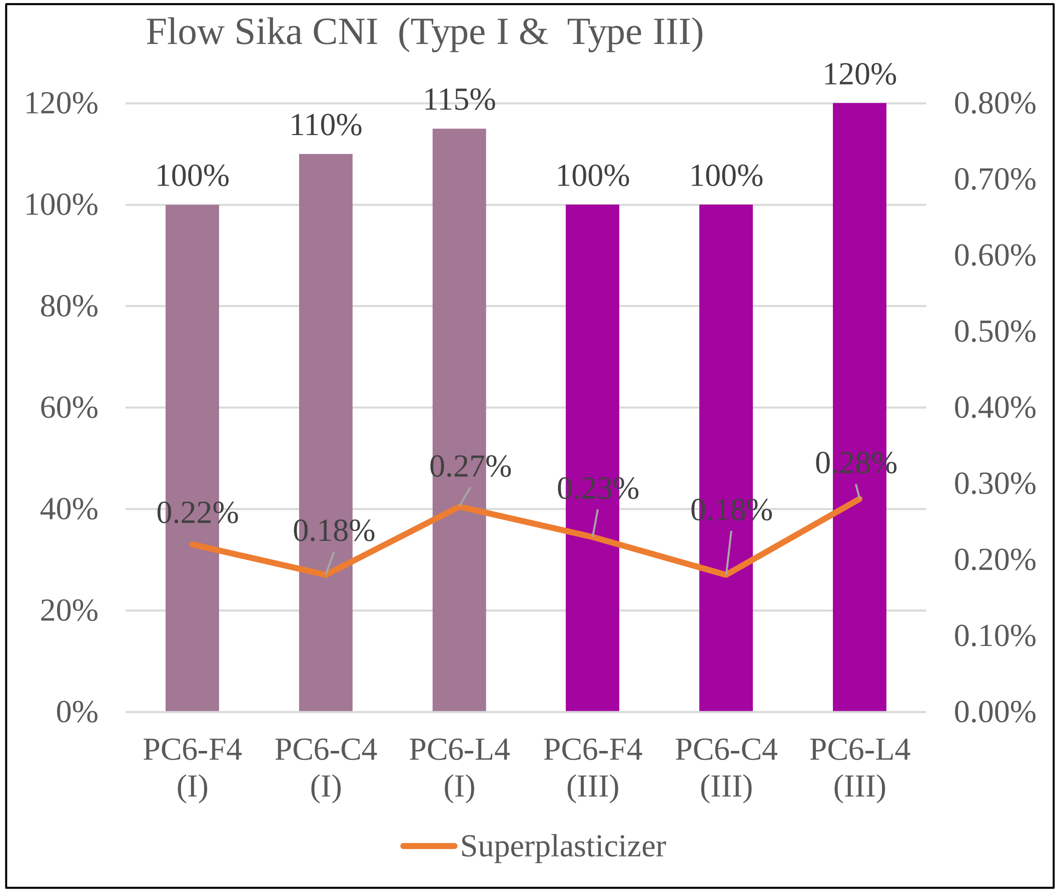
Evaluation of HVFA ***[binary]*** **binders** (Task 3) cont…





Evaluation of HVFA ***[binary]*** **binders** (Task 3) cont…





Evaluation of HVFA ***[ternary]*** **binders** (Task 3)

Test Matrix

1- 0% - 10 % - 20 % Calcined Clay

2- 0% - 5% - 10% Silica Fume

3- 0% -20 % Slag (w & w/o NaOH)

4- 0% - 20 % - 30% - 40 % CSA

Successful Test Matrix

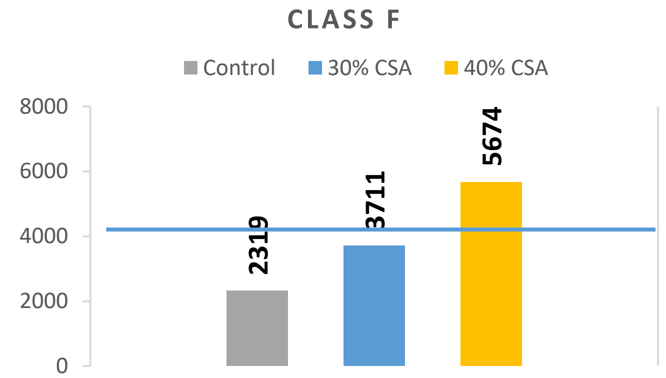
Class F → 40 % CSA

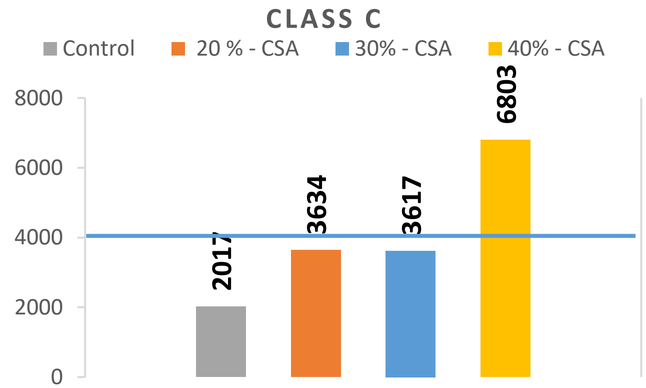
Class C → 40% CSA

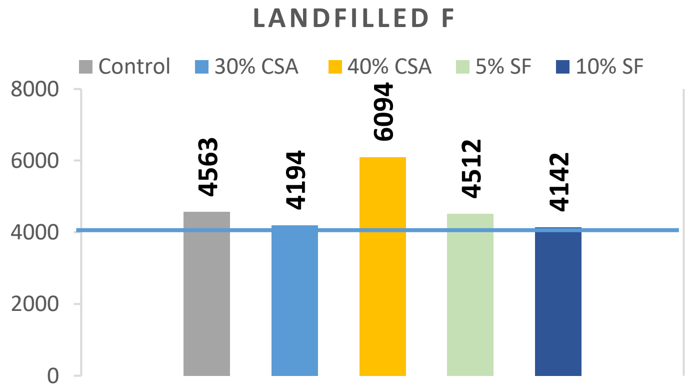
Landfilled F →30 % CSA, 40% CSA, 5% SF, 10% SF

Cementitious Materials:

Material	Unit Cost ($/ton)	Source
Type I	$160	Lehigh Hanson
Type III	$175	Lehigh Hanson
CSA	$600	Buzzi CSA
Fly Ash	$110	Boral







Gypsum optimization (Task 3)

Determine **SO_3** Content of Binder

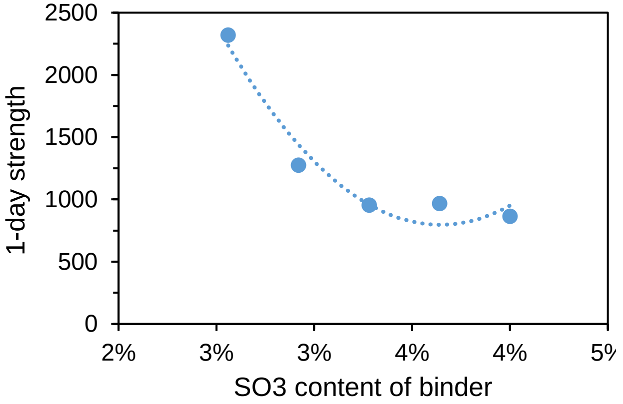
Material	SO3 (XRF)
Type III	2.80%
Class F	2.20%
Class C	2.00%
Landfilled	0.46%
Gypsum	46.5%

ASTM - C563: Standard Guide For Approximation of Optimum SO_3 in Hydraulic Cement.

ASTM- C595: Standard Specification for Blended Hydraulic Cements determines the maximum sulfate reported as SO_3 as **"4%"**

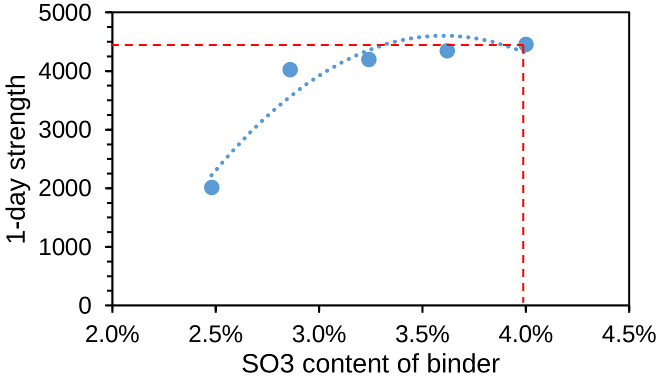
Class F

Mix	SO3 Content	1 day strength
F-G0	2.56%	2319
F-G1	2.92%	1276
F-G2	3.28%	954
F-G3	3.64%	967
F-G4	4.00%	865



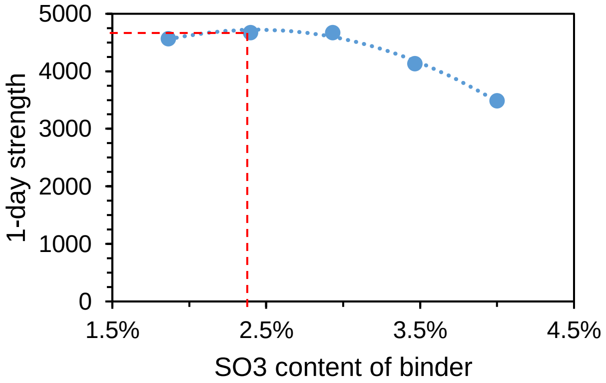
Class C

Mix	SO3 Content	1 day strength
C-G0	2.48%	2017
C-G1	2.86%	4025
C-G2	3.24%	4200
C-G3	3.62%	4349
C-G4	4.00%	4455



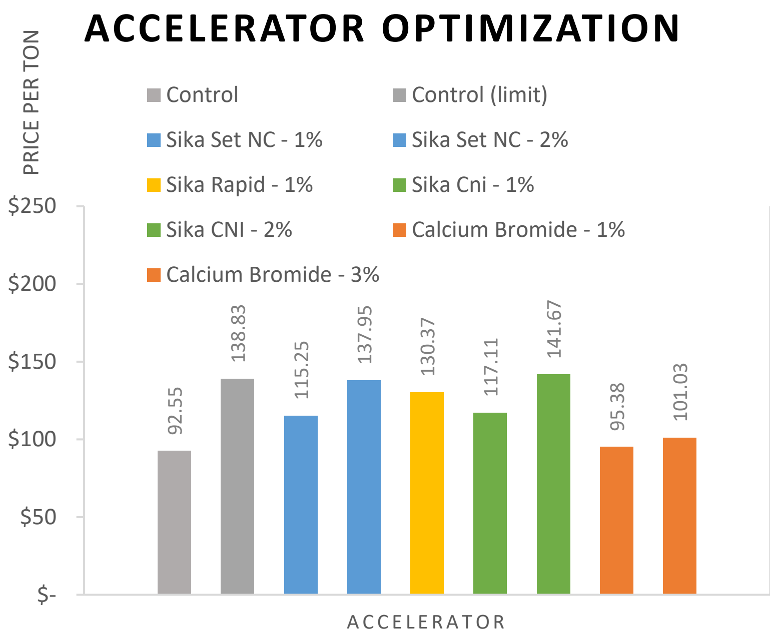
Landfilled

Mix	SO3 Content	1 day strength
L-G0	1.86%	4563
L-G1	2.40%	4670
L-G2	2.93%	4671
L-G3	3.47%	4131
L-G4	4.00%	3483



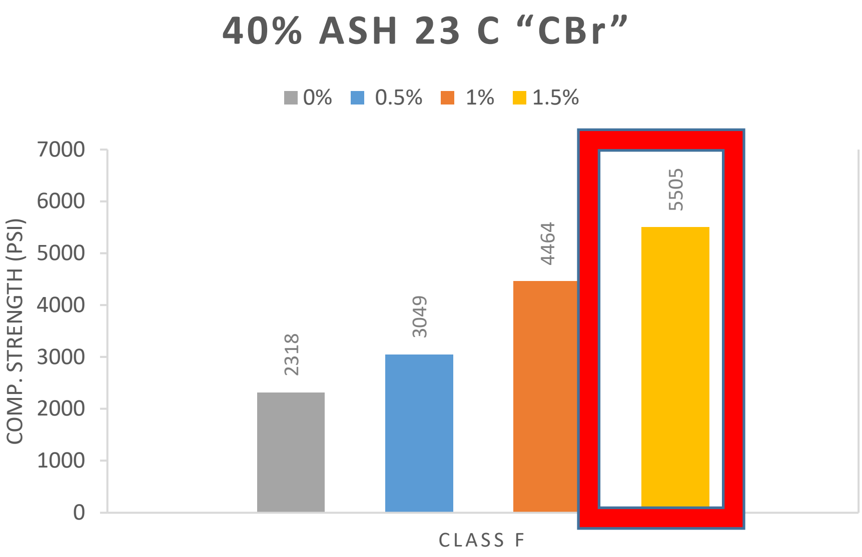
Accelerator [admixture] **optimization** (Task 3)

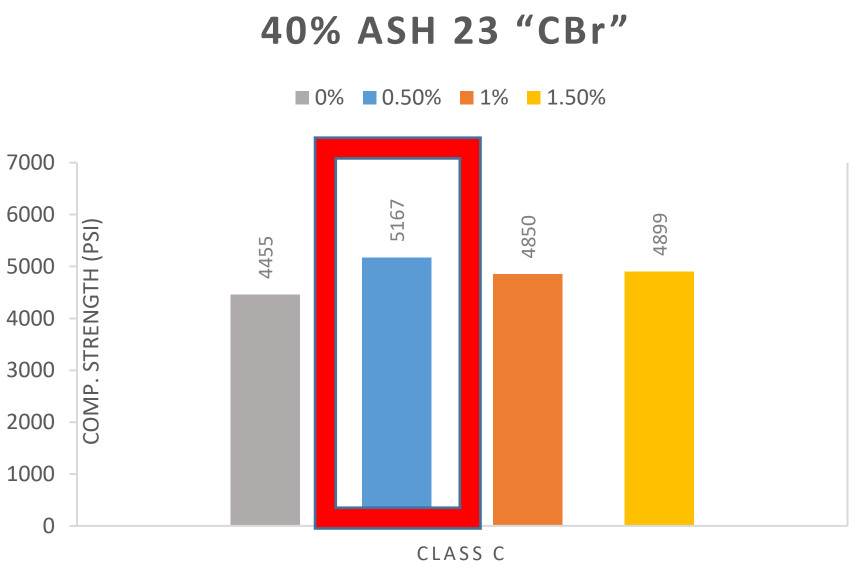
→ **GOAL:** Balancing of optimized cost and 24-hour strength performance

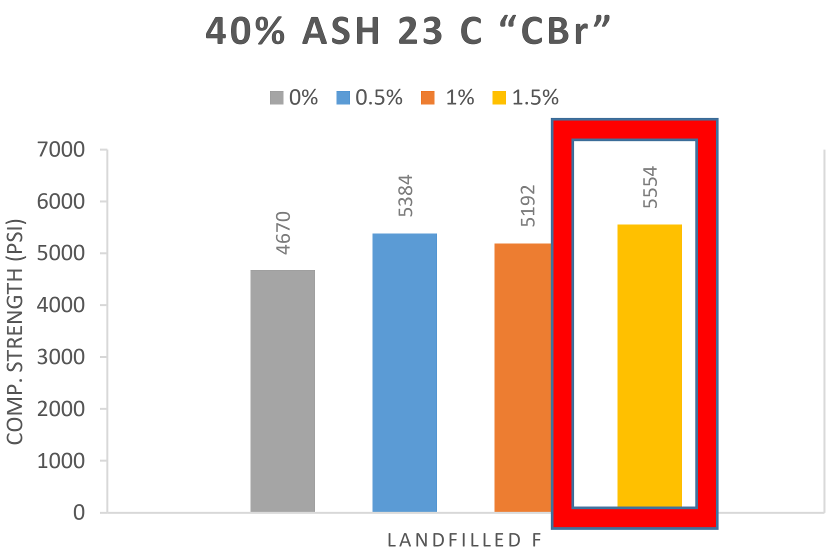


	Class F				Class C				Landfilled			
	Sika Cni	Sika Set NC	Calcium Bromide	Sika Rapid 1	Sika Cni	Sika Set NC	Calcium Bromide	Sika Rapid 1	Sika Cni	Sika Set NC	Calcium Bromide	Sika Rapid 1
Optimal %	1%	1%	1.50%	0.50%	0%	0%	0.50%	0%	1%	1%	1.50%	0.50%
Strength	4688	4167	5505	4446	4455	4455	5156	4455	5476	5269	5554	5134

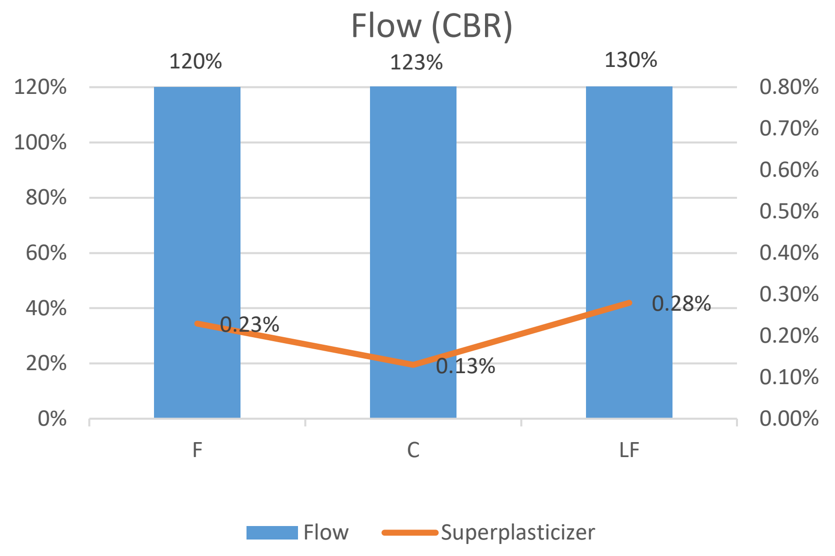
Calcium Bromide optimization (Task 3)

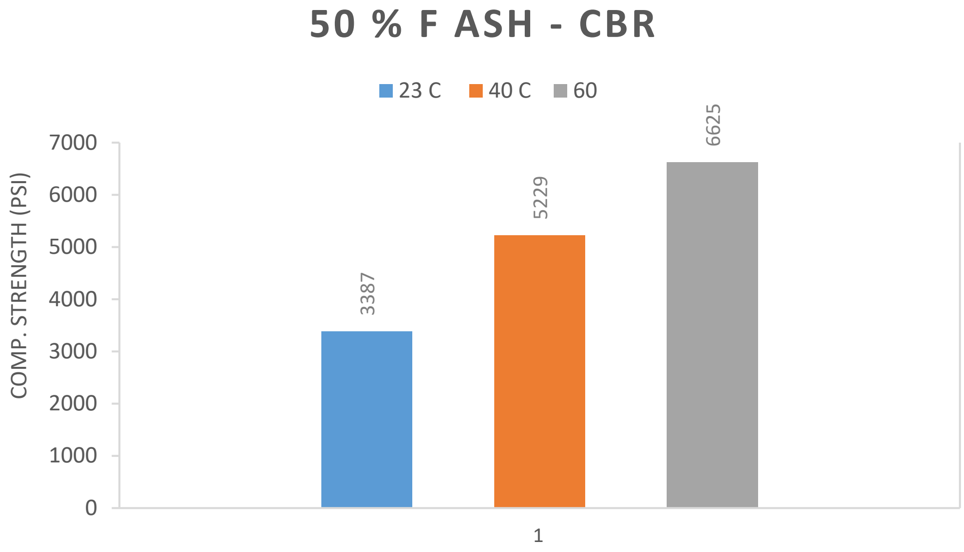


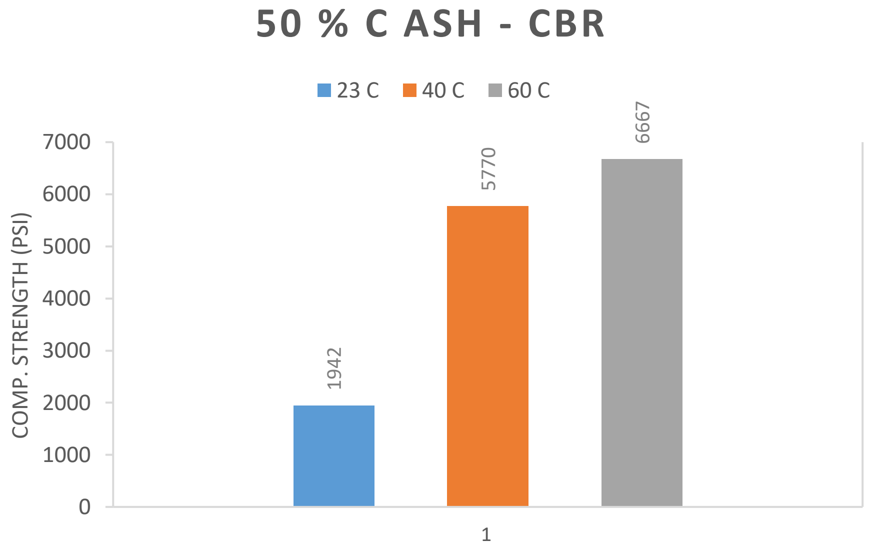


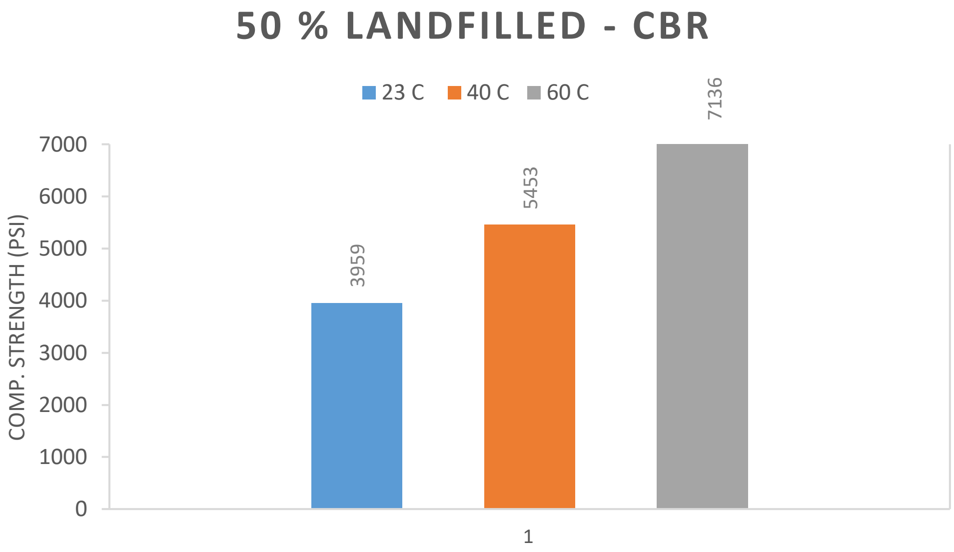


Heat Curing – 50 % FA + CBR (Task 3)









Preliminary Evaluation of HVFA **Concretes** (Task 4) cont…

Summary of preliminary trial HVFA hardened concrete performance

Mix ID	Break Time (hr)	Avg. Comp. Strength (psi)	MOR (psi)	Design MOR (psi)
0.32-C25	18	4006	-	475
	21	4360	586	495
	24	4810	697	520
0.32-F40	18	1340	-	275
	24	3303	-	431
0.32-C40A	18	3906	-	469
	21	4483	-	502
	24	4923	-	526
0.32-C40B	18	1570	-	297
	21	1790	401	317
	24	2050	-	340
0.32-C50	18	1773	-	316
	21	2276	-	358
	24	2673	-	388
0.35-F25	24	4926	-	526

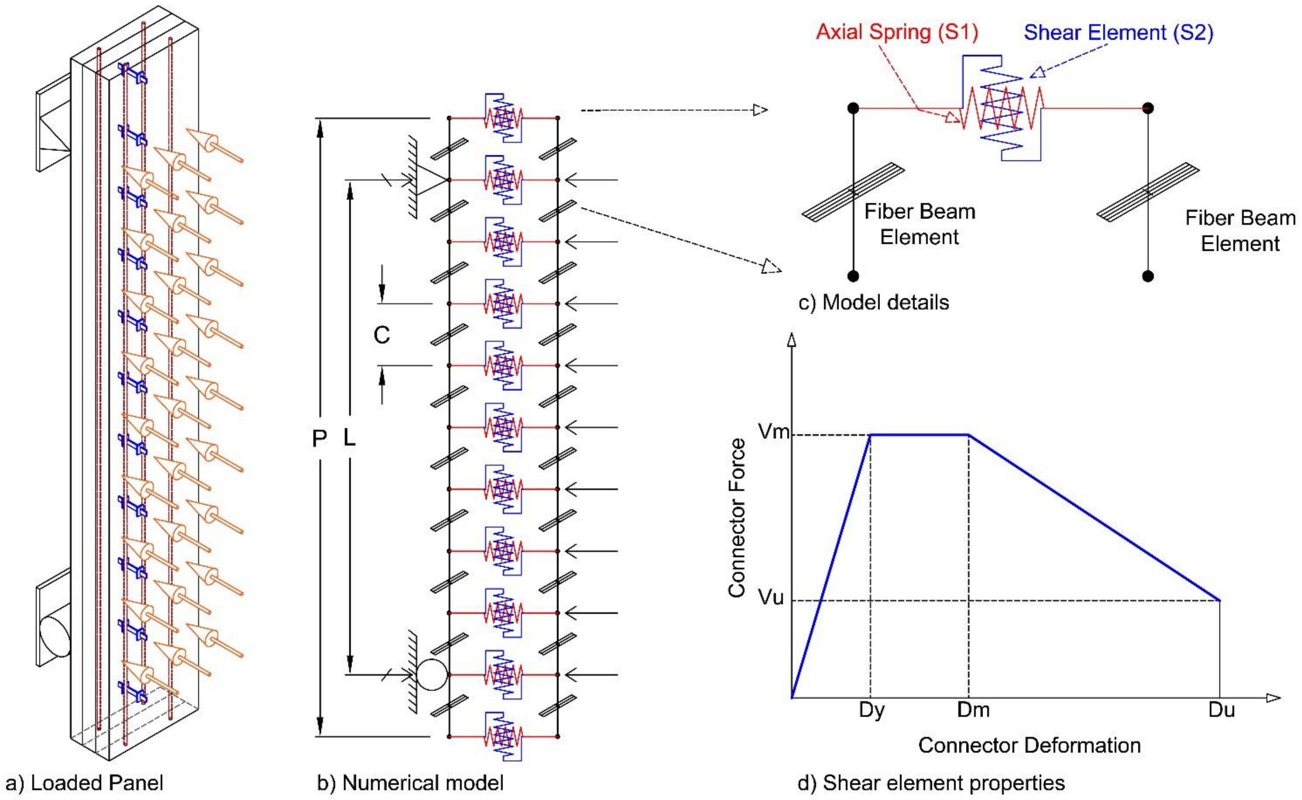
*Note: MOR = modulus of rupture

Preliminary Structural Modeling of **Precast Components** (Task 5)

→ Initial modeling efforts commenced recently

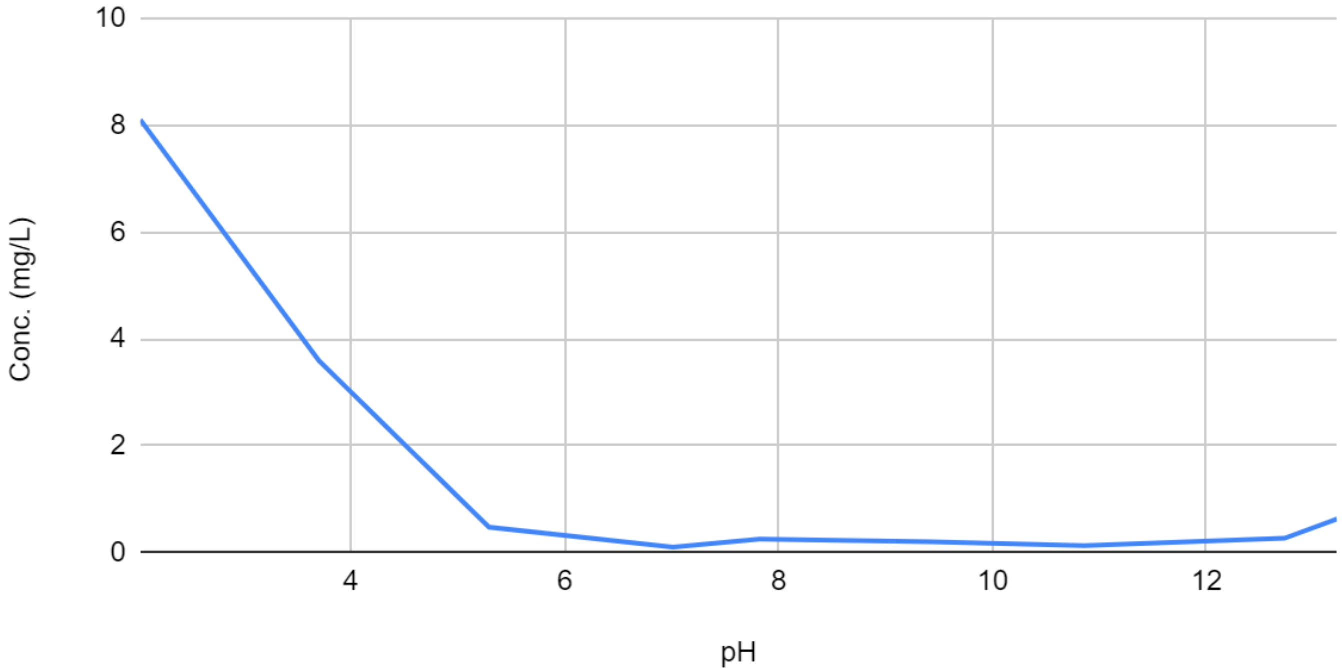
→ Will serve as valuable link between material properties and predicting the performance of structural precast components

→ Will be validated after experimental testing later in Task 5



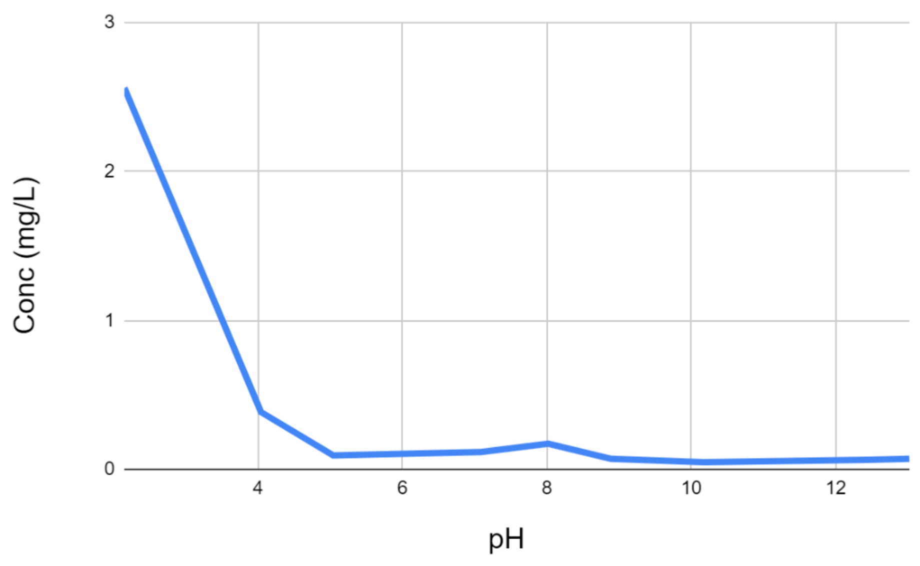
Environmental Life-Cycle Considerations (Task 6)

One of the fly ash samples exceeded the EPA drinking water limit for chromium. The general trends indicate that the chromium concentration increased as pH decreased. These results represent a maximum potential from the fly ash – once the samples are encapsulated in concrete the available COPCs are expected to be lower.

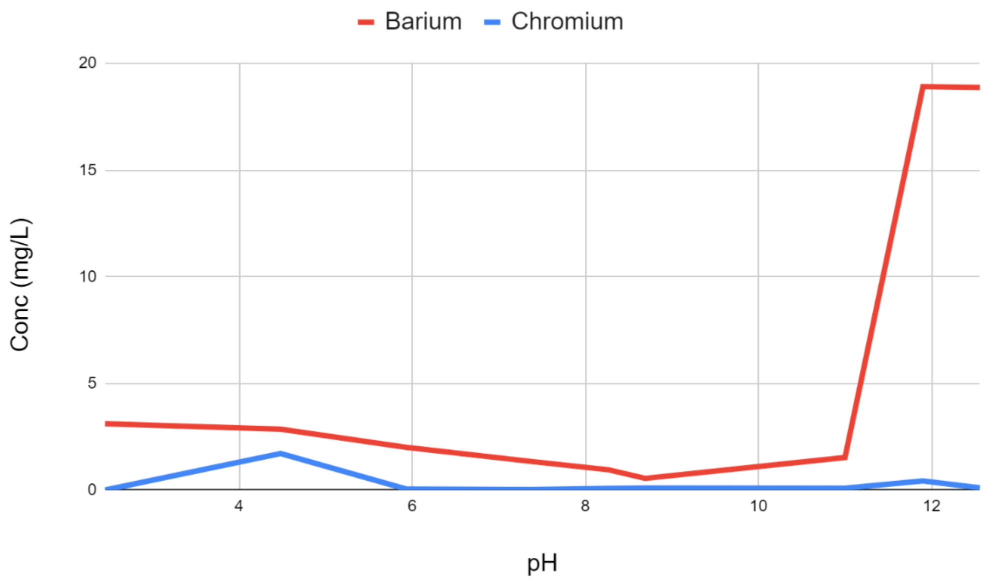


Chromium concentration from EPA Method 1313 for **fresh Class F** Fly Ash sample.

Environmental Life-Cycle Considerations (Task 6) cont…



Chromium concentration from EPA Method 1313 for **harvested Class F** Fly Ash sample.



Chromium and Barium concentrations for EPA Method 1313 for **fresh Class C** Fly Ash.

These results show that the effluent increases with decreasing pH and barium increases with increasing pH.

Once again, these results represent a maximum potential from the fly ash – once the samples are encapsulated in concrete the available COPCs are expected to be lower.

Upcoming Work

Microstructure evaluation of HVFA binders (Task 3)

Extrapolation of favorable HVFA binders to HVFA concrete mix designs (Task 4)

Extensive mechanical testing of hardened HVFA concrete samples (Task 4)

Computational modeling of precast concrete structural components (Task 5)

Ongoing environmental testing on hardened HVFA binder specimens (Task 6)

Questions ?

Thank You!