MCPT Based Approach Towards Evaluating ASR Potential of Job Concrete Mixtures

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AAR Test Methods for Aggregate Characterization

ASR

- ASTM C 227 – Mortar Bar Test (withdrawn, 2018)
- ASTM C 289 – Quick Chemical Test (withdrawn, 2016)
- ASTM C 295 – Petrographic Examination
- ASTM C 1260 – Acc. Mortar Bar Test (16 days)
- ASTM C 1293 – Concrete Prism Test (365 days)
- AASHTO T380 – Miniature Concrete Prism Test (56 – 84 days)
- Other AASHTO Test Methods (TFAST, VMCD)

ACR

- ASTM C 295 – Petrographic Examination
- ASTM C 586 – Rock Cylinder Test (ACR)
- ASTM C 1105 – Concrete Prism Test (ACR)

Existing Test Methods to Evaluate ASR Mitigation

- ASTM C441 – Mortar Bar Test w/ Pyrex Glass (14 days)
- ASTM C1567 – ASR Mitigation (AASHTO T303) (14 days)
- COE CRD-C-662 – ASR Mitigation (Lithium) (28 days)
- ASTM C1293 – ASR Mitigation (2 years = 730 days)
- AASHTO T380 – Miniature Concrete Prism Test (56 days)

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ASTM C441 Test Method

- Mortar Bars with Binders Used in Combination with Pyrex Glass Aggregate
  - High-Alkali Portland Cement (HA-PC) ($Na_2O_{eq.}$ Between 0.95 and 1.05)
  - Pozzolans (25%) or Slag(50%)
  - Job Cementitious Materials
- Water-to-binder ratio: 0.45

Three Sets of Specimens

- Control Mixture (E_r): Mortar with HA-PC Only
- Test Mixture (E_t): Mortar with Blend of HA-PC & Pozzolan(25%) or Slag (50%)
- Job Mixture (E_j): Any Portland Cement and Any Replacement Level of Pozzolan or Slag

Percent Reduction in Expansion (R_e)

$$R_e = (E_r - E_t) \times 100/E_r$$

MCPT Method – Aggregate Characterization Test

- Concrete Prisms = 2 in. x 2 in. x 11.25 in.
- Coarse Agg. Size Range = No. 4 – 1/2 in.
- Coarse Agg. Vol Fraction (Dry-Rod) = 0.65
- Coarse Agg. Grading Requirement

Sieve Size, mm		Mass, %
Passing	Retained	
12.5	9.5	57.5
9.5	4.75	42.5

- Cement Content = 708 lb/yd³ (420 kg/m³)
- Cement Alkali Content = 0.9% ± 0.1% $Na_2O_{eq.}$
- Alkali Boost, (Total Alkali Content) = 1.25% $Na_2O_{eq.}$
- Water-to-cement ratio (fixed) = 0.45

(Pore Solution) 1N NaOH

- Storage Environment* = 1N NaOH Solution (Soak Solution)
- Storage Temperature = 60°C

MCPT Method – ASR Mitigation Evaluation

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MCPT Criteria for Aggregate Reactivity Characterization

Degree of Reactivity	Expansion at 56 Days, % (8 Weeks)	Average 2-Week Rate of Expansion from 8 to 12 Weeks[a]
Nonreactive	≤0.030	N/A[b]
Nonreactive	0.031–0.040	≤0.010% per 2 weeks
Low/slow reactive	0.031–0.040	>0.010% per 2 weeks
Moderate reactive	0.041–0.120	N/A[b]
Highly reactive	0.121–0.240	N/A[b]
Very highly reactive	>0.240	N/A[b]

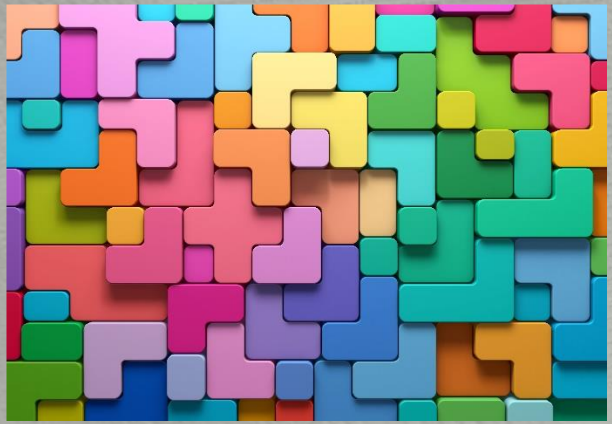
MCPT Criteria for Evaluation of SCMs

Efficiency of Mitigation	Expansion at 56 Days, % (8 Weeks)
Effective	<0.020
Uncertain[a]	0.020%–0.025
Not effective	>0.025

[a] Recommend retest with MCPT using a higher dosage of mitigation.

Influence of Job Mix Parameters on ASR Expansion

- Typical job mix parameters that differ from the standard MCPT method are:
  - w/c and w/cm ratios
  - Total cementitious materials content
  - Total alkali loading in concrete
  - Dosage of SCMs
  - Vol. fraction of aggregates in concrete
  - Presence of blended aggregates with competing reactivity



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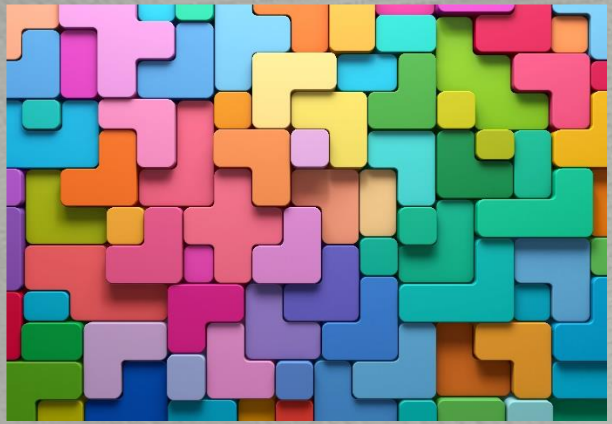

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Chemical Composition of Binders

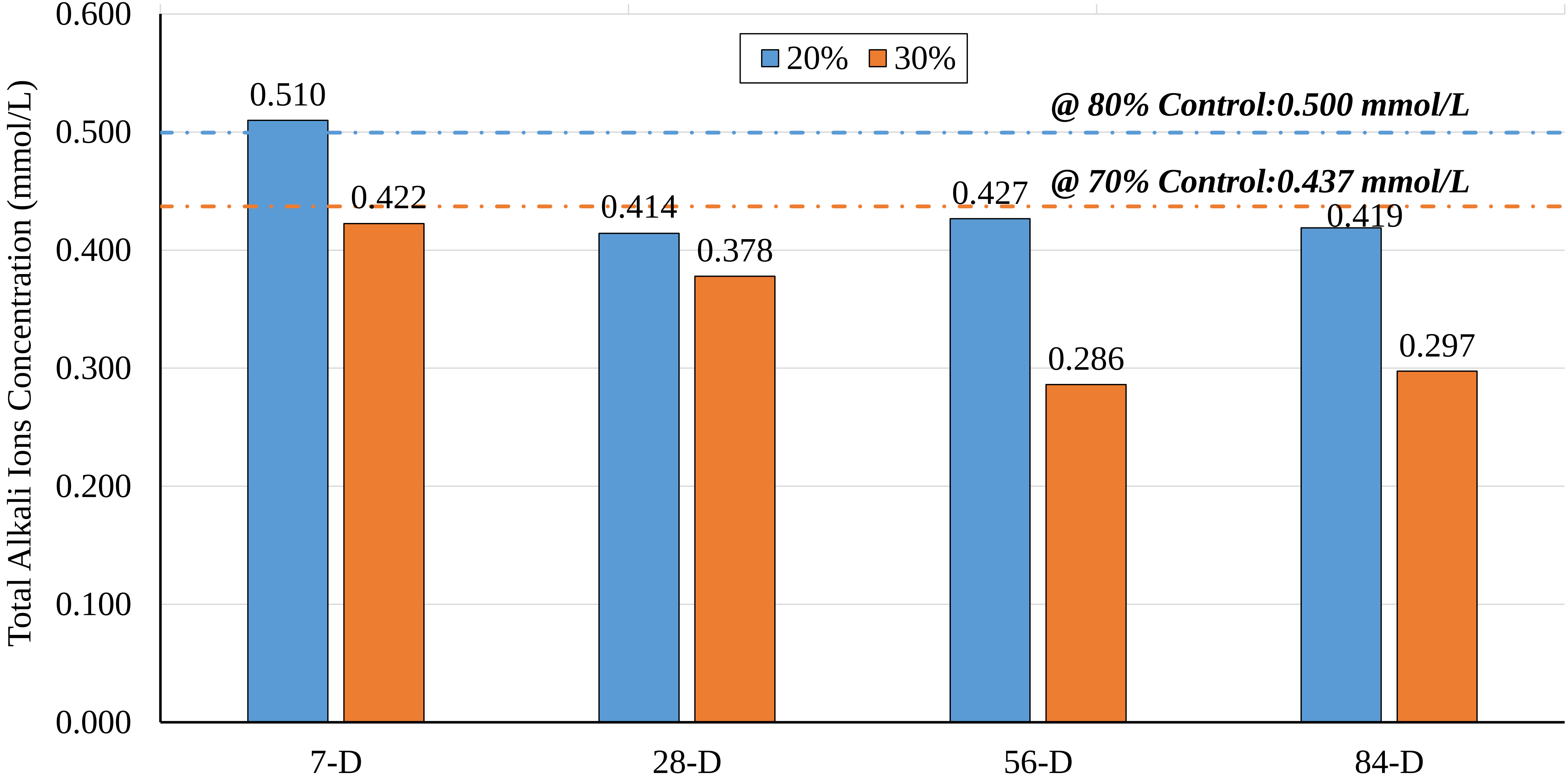
Oxide	Notation	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Na_2O_e	LOI	SG
High-alkali cement	HA	19.00	4.99	2.11	62.45	2.84	0.31	1.05	1.0	-	3.15
Volcanic rhyolitic tephra	NP	71.95	12.26	1.50	0.93	0.39	3.9	4.0	6.51	4.88	2.35

Aggregate – Siliceous Argillite Aggregate from Goldhill Quarry, NC

Predicted Pore Solution Alkalinity (Stark et al., SHRP-C-342 Report):

$(OH-) = (0.339*Na_2O_{eq}\%) / (w/c) + 0.022 \pm 0.06 mol/L$

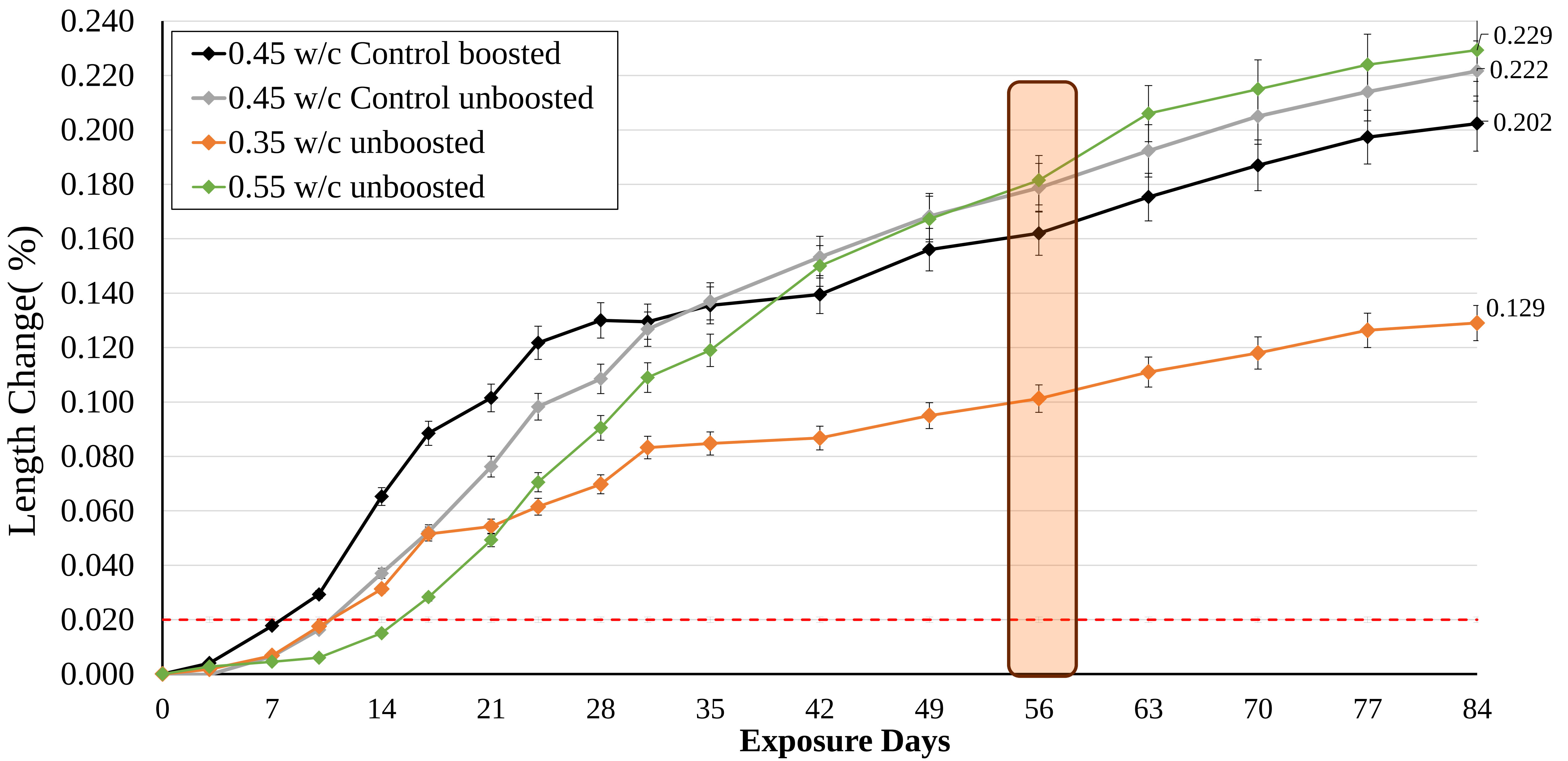
Expressed Pore Solution Composition from Binder Pastes containing NP (w/cm = 0.45)



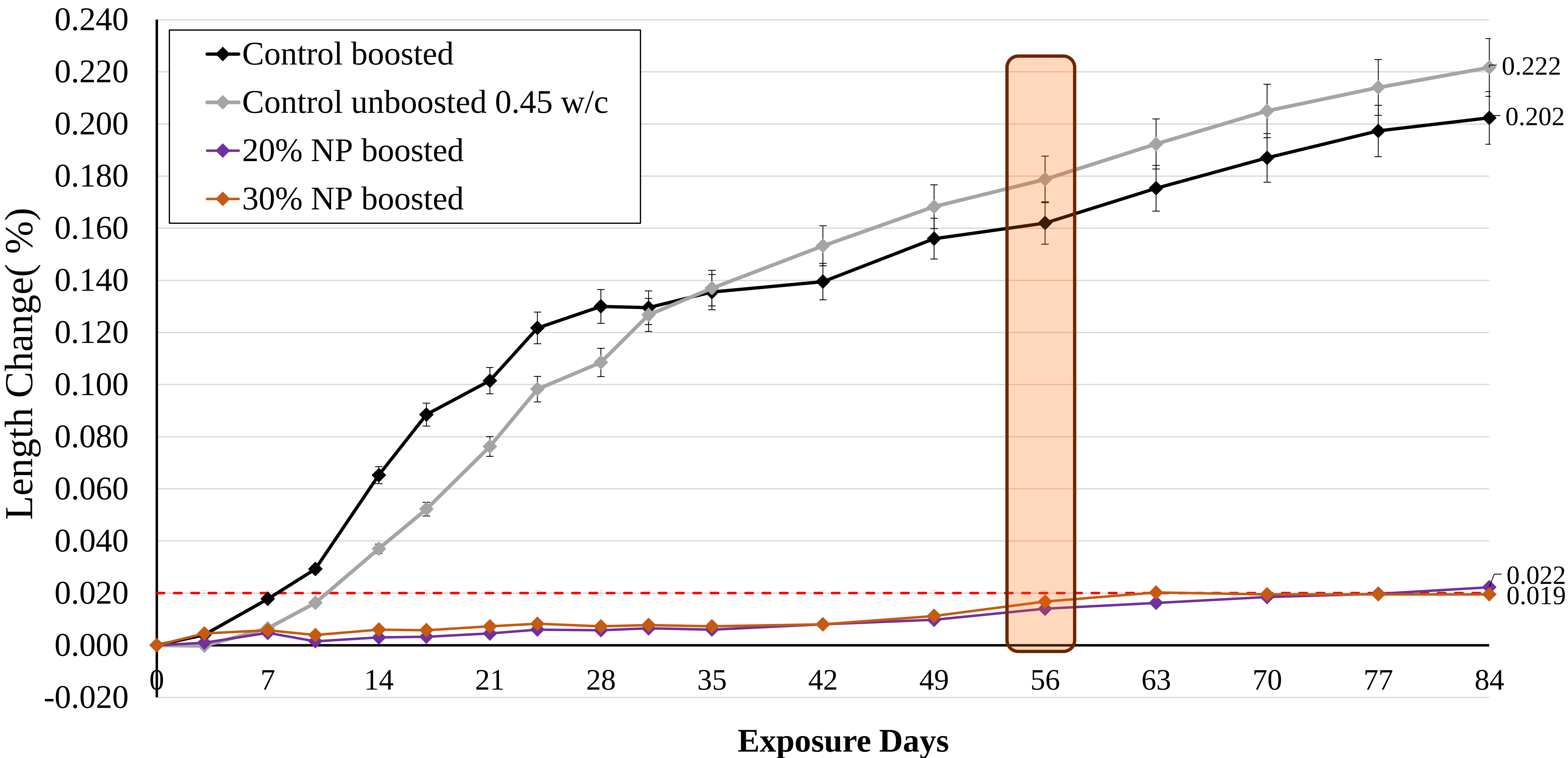
Design of Soak Solution Concentration

No.	Label	Soak Solution (OH-) (mol/L)	Pore Solution (OH-) (mol/L)	Cement Na_2O_{eq} (%)	**w/cm = 0.45** w/c	Alkali Loading (lbs/yd^3)
1	Control boosted (w/c=0.45)	1.00	0.96	1.25	0.45	8.85
2	0.35 w/c unboosted	1.05	0.99	1	0.35	7.08
3	0.45 w/c unboosted	0.85	0.78	1	0.45	7.08
4	0.55 w/c unboosted	0.70	0.64	1	0.55	7.08

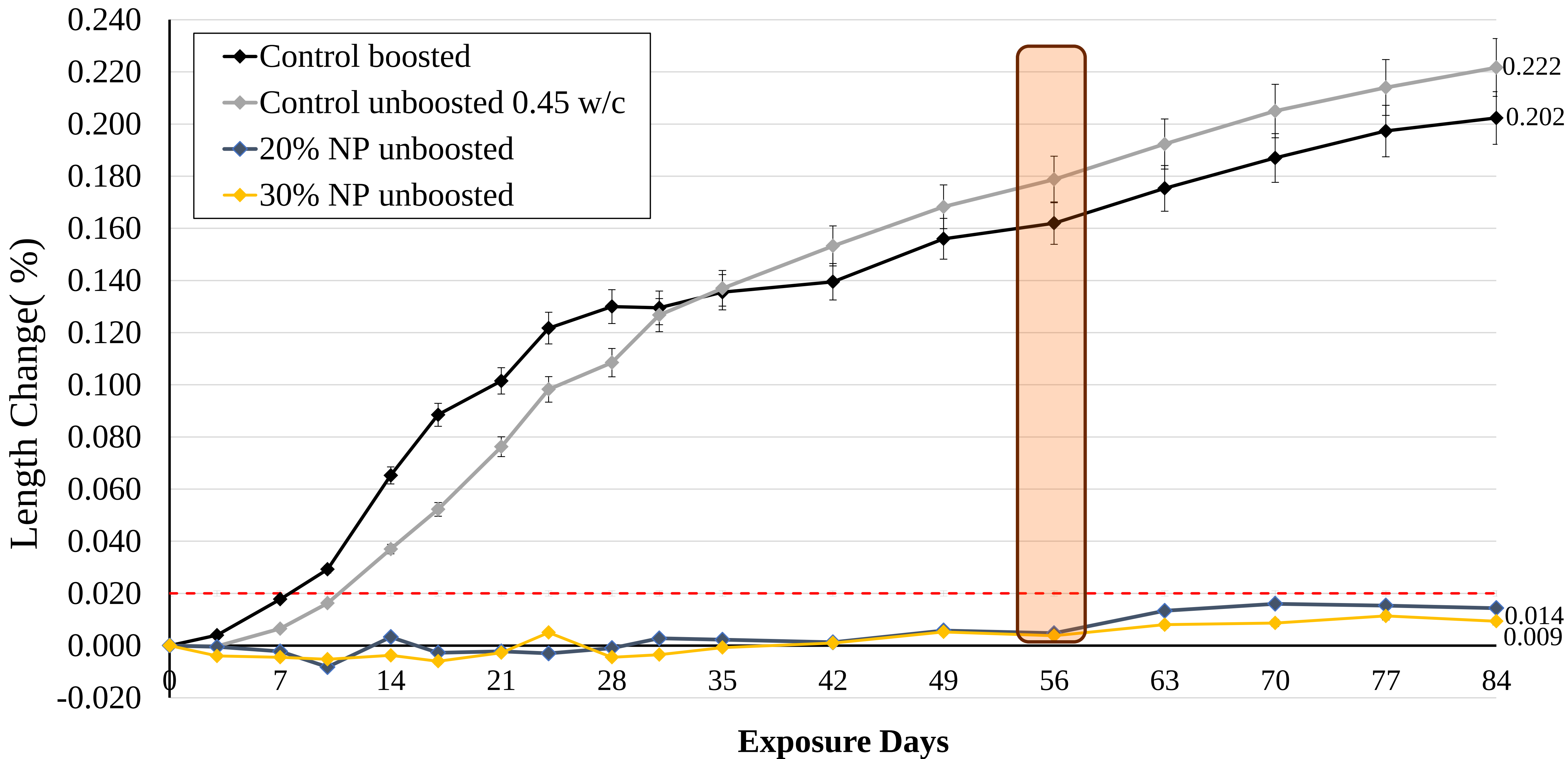
Impact of w/c ratio and no alkali boosting on MCPT Expansion of Straight Portland Cement Mixtures



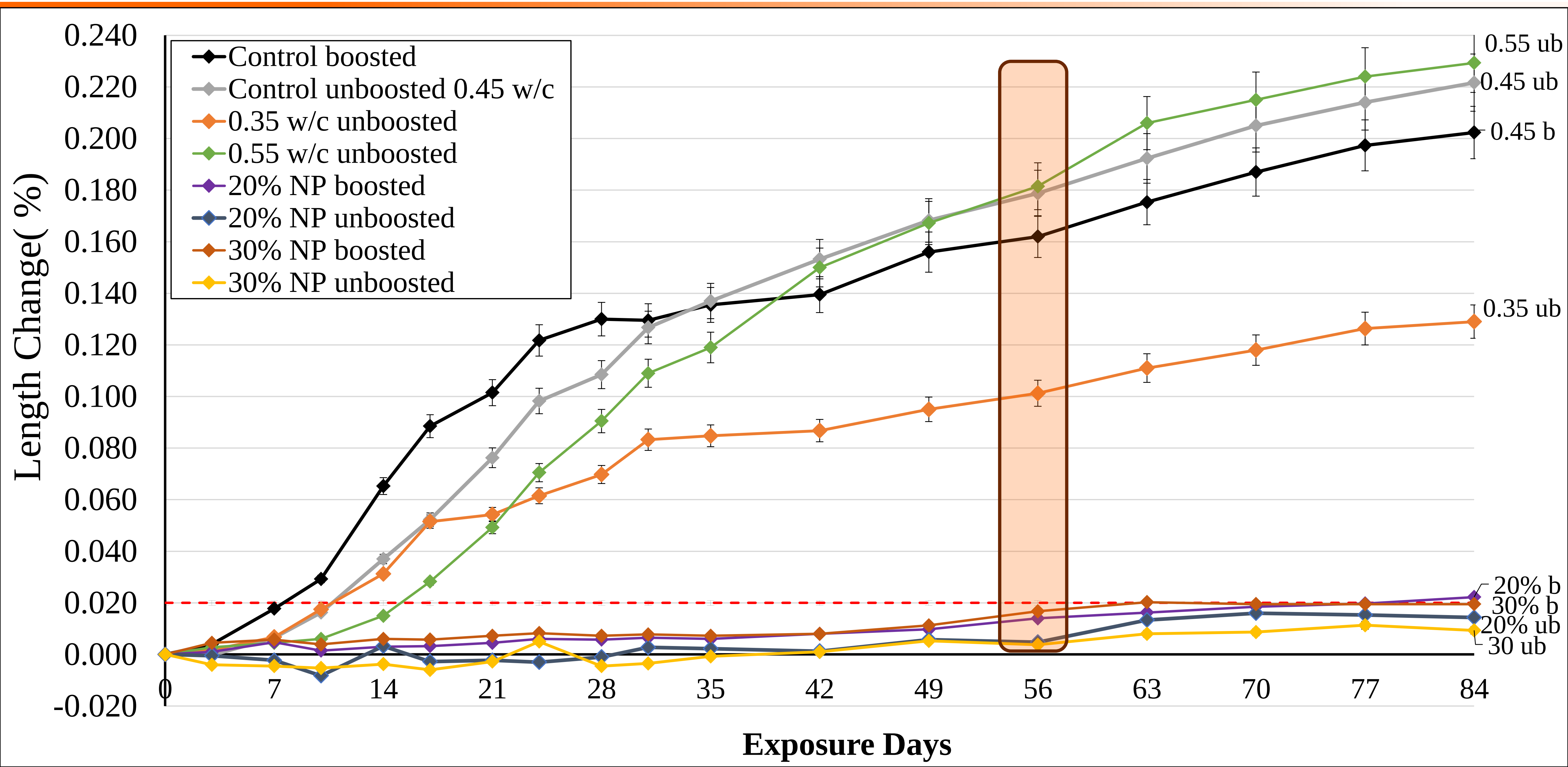
Impact of Pozzolan Replacement Level on Expansion (Boosted)



Impact of Pozzolan Replacement Level (Unboosted)

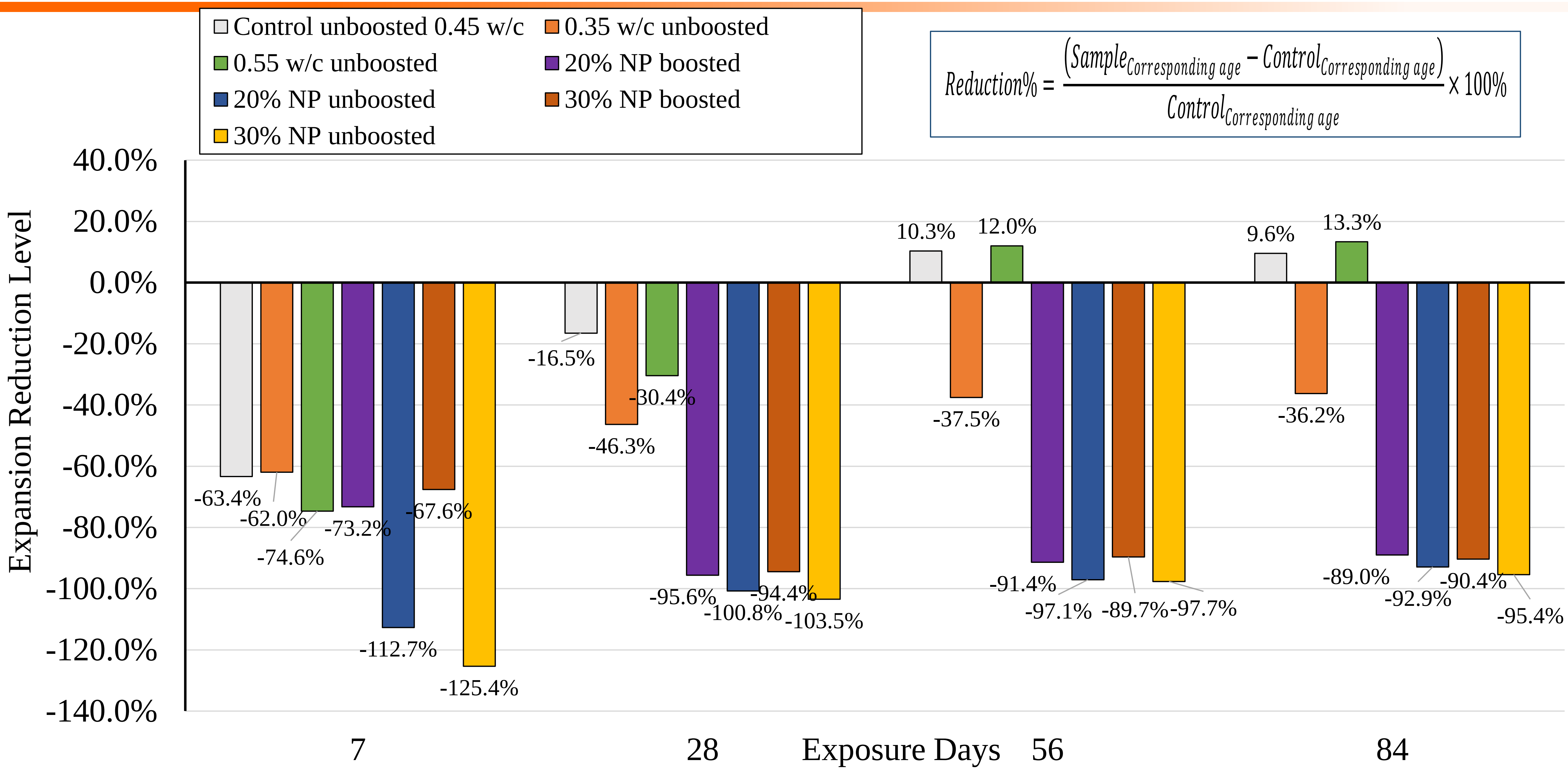


Summary of Results

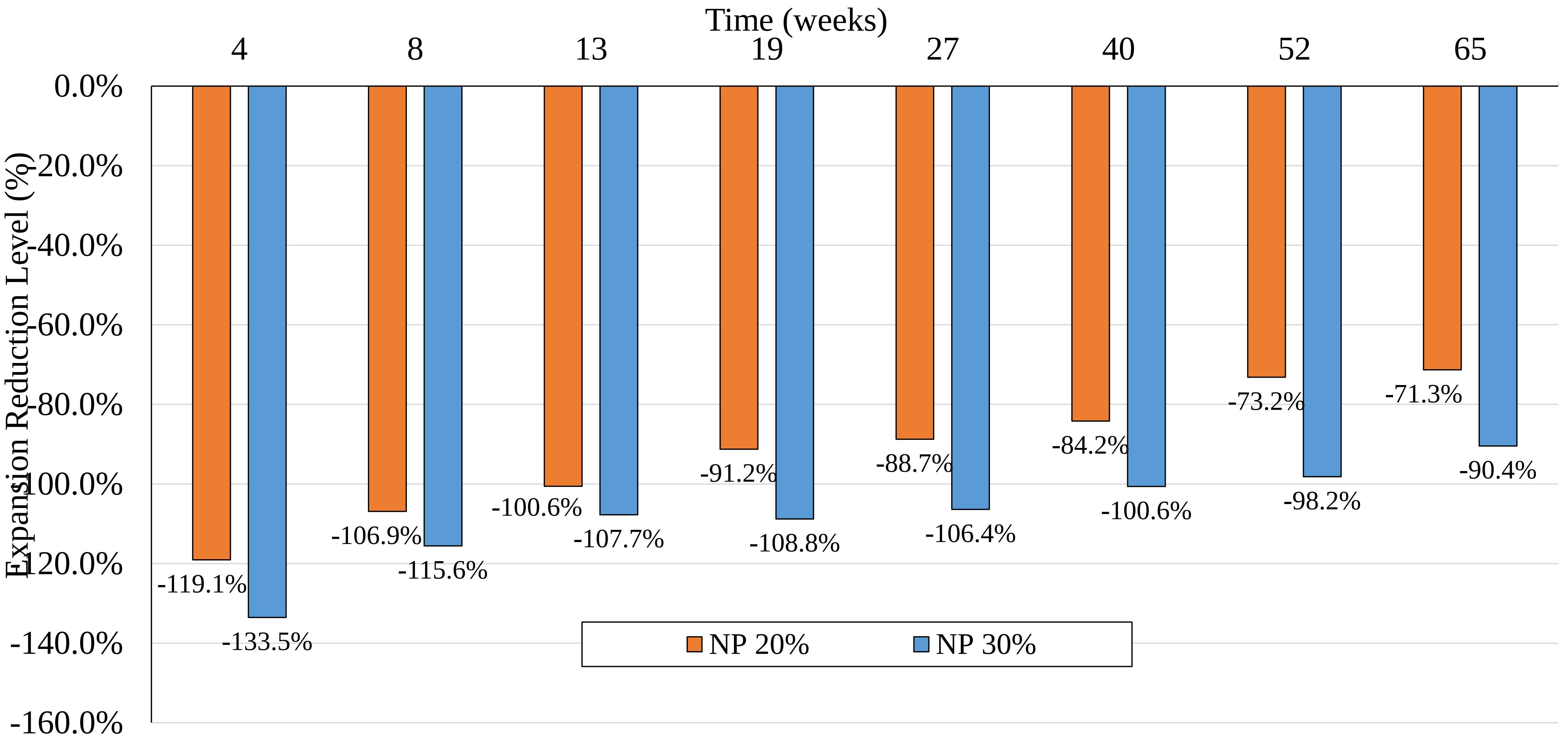


Percent Reduction in Expansion in MCPT

$$Reduction\% = \frac{(Sample_{Corresponding\ age} - Control_{Corresponding\ age})}{Control_{Corresponding\ age}} \times 100\%$$



Percent Reduction in Expansion in ASTM C1293

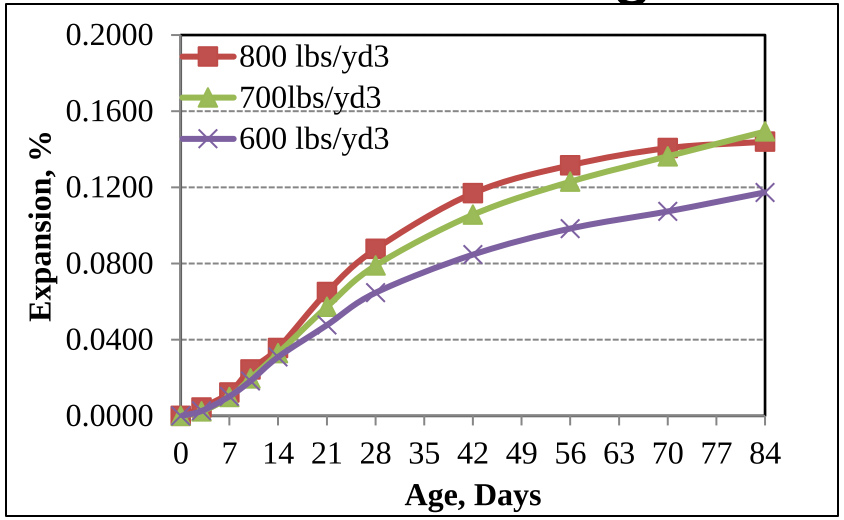


Effect of cement content / total alkali loading in concrete on MCPT expansion

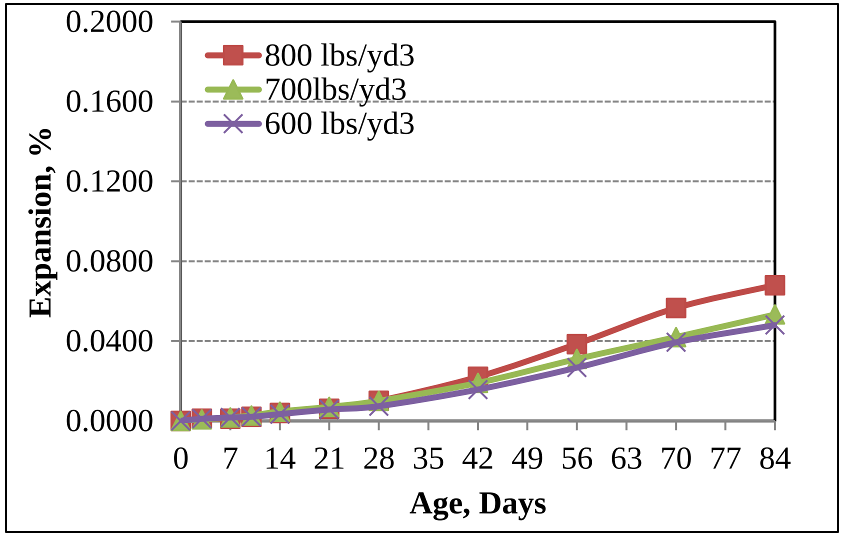
	Cement Content, lb/yd^3	Total Alkali Loading (lb/yd^3)	56-Day Expansion (%)
LA Cement	600 (Na_2O_{eq}. = 0.49%)	2.94	0.027
	700 (Na_2O_{eq}. = 0.49%)	3.43	0.031
	800 (Na_2O_{eq}. = 0.49%)	3.92	0.039

Effect of cement content on expansion in MCPT with High and Low Alkali Cement

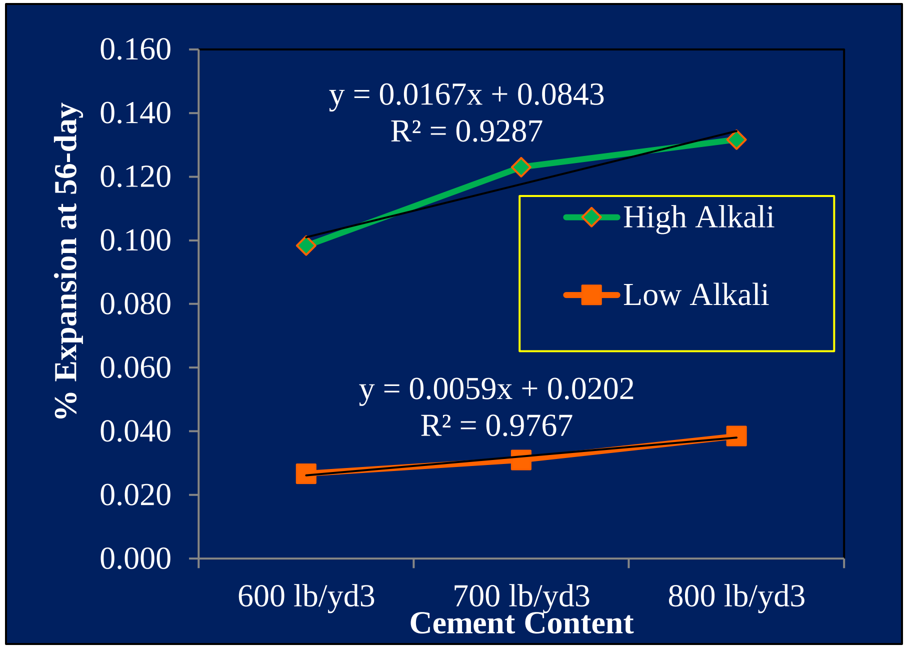
High Alkali



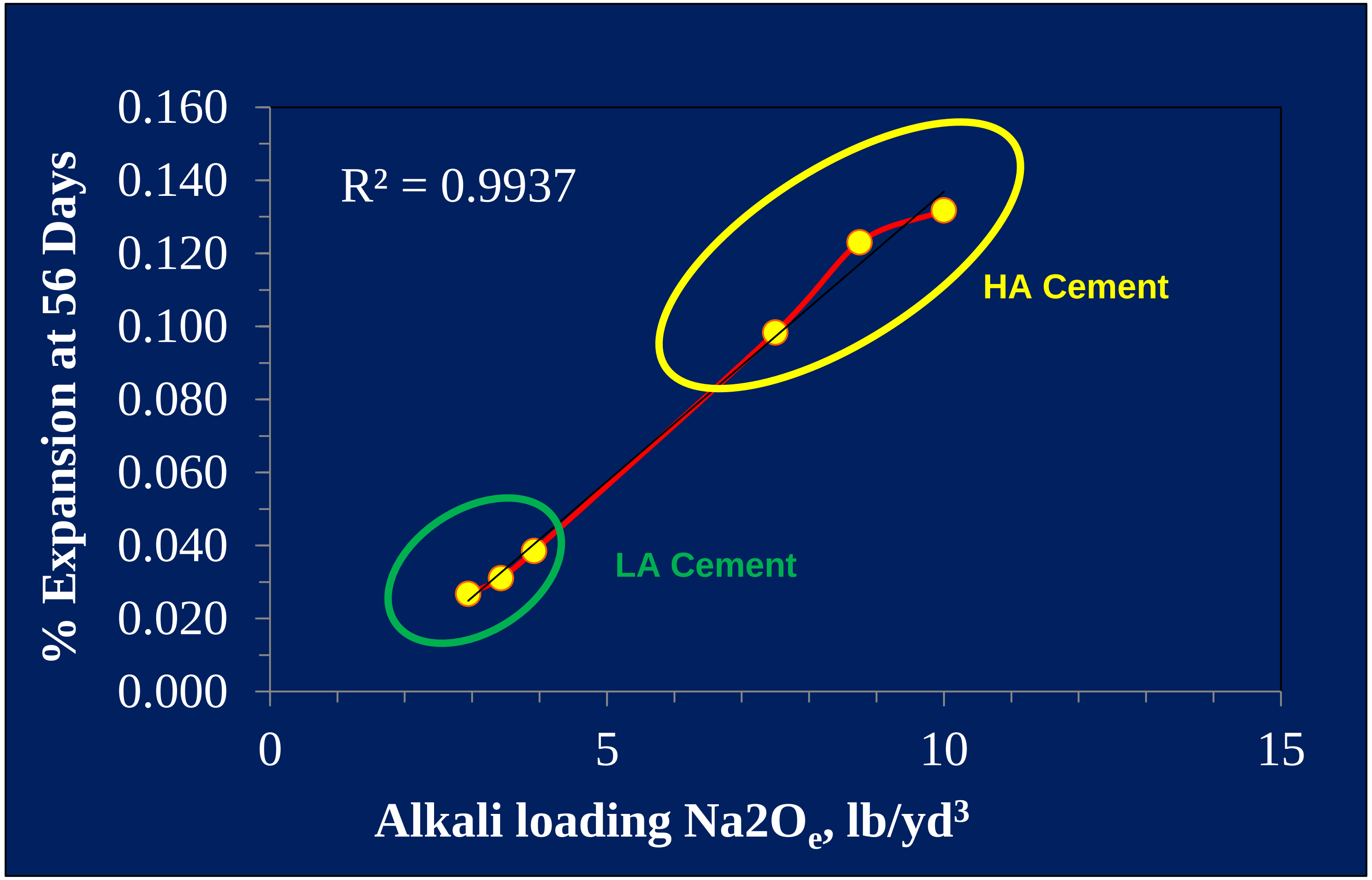
Low Alkali



w/c =0.45



Effect of Alkali Loading in Concrete on Expansion in MCPT



Application of MCPT to Job Mixtures

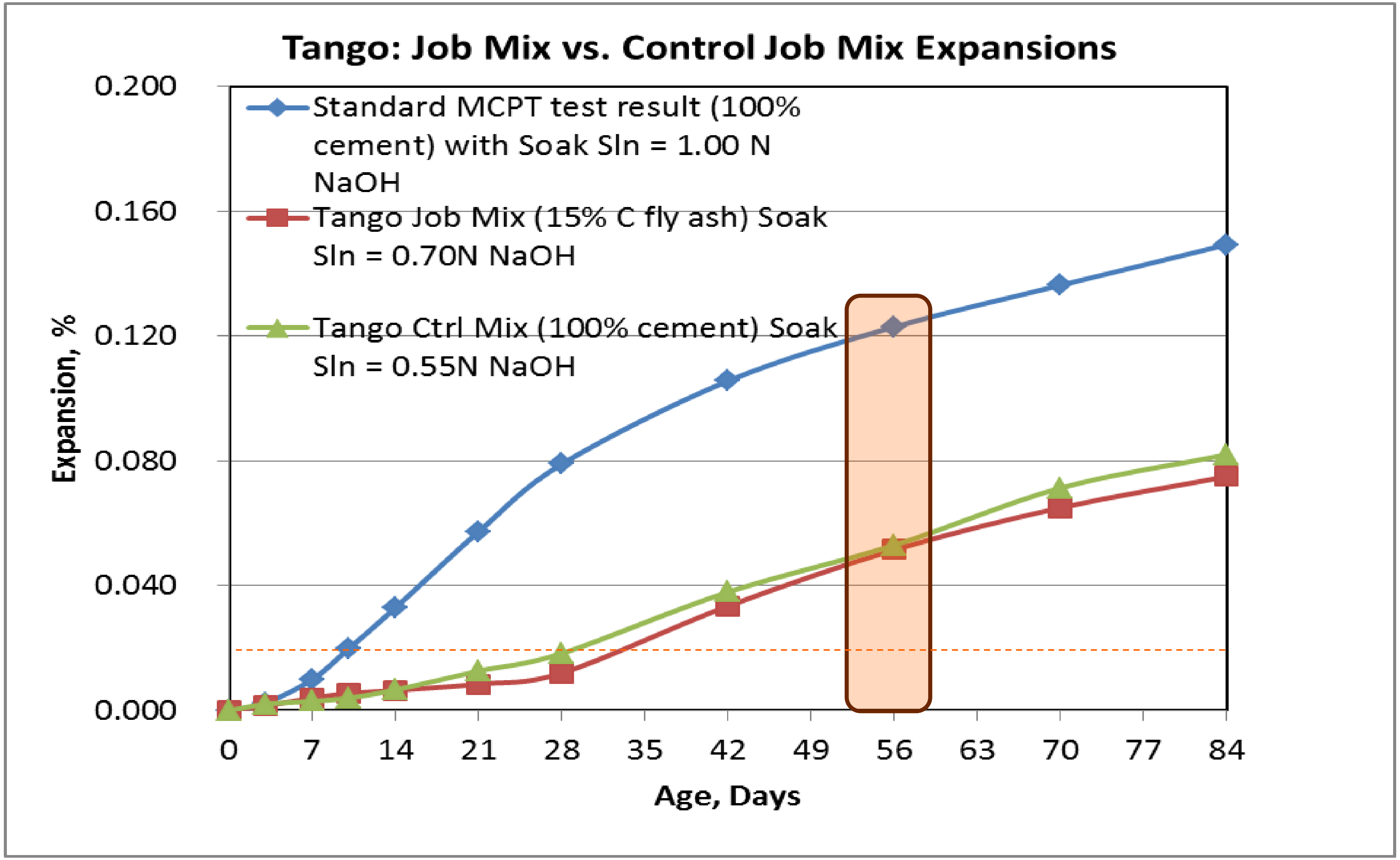
- Airfield pavements that exhibited premature distress due to ASR was used as a case study
- Prepared standard MCPT mixtures
- Prepare job mix MCPT specimens with certain exceptions to specifications:
  - Aggregate Gradation to Match Std. Requirements, i.e., max. aggregate size = ½ in.
- Match soak solution concentration to pore solution concentration of job mixture

Evaluation of Job Mixtures

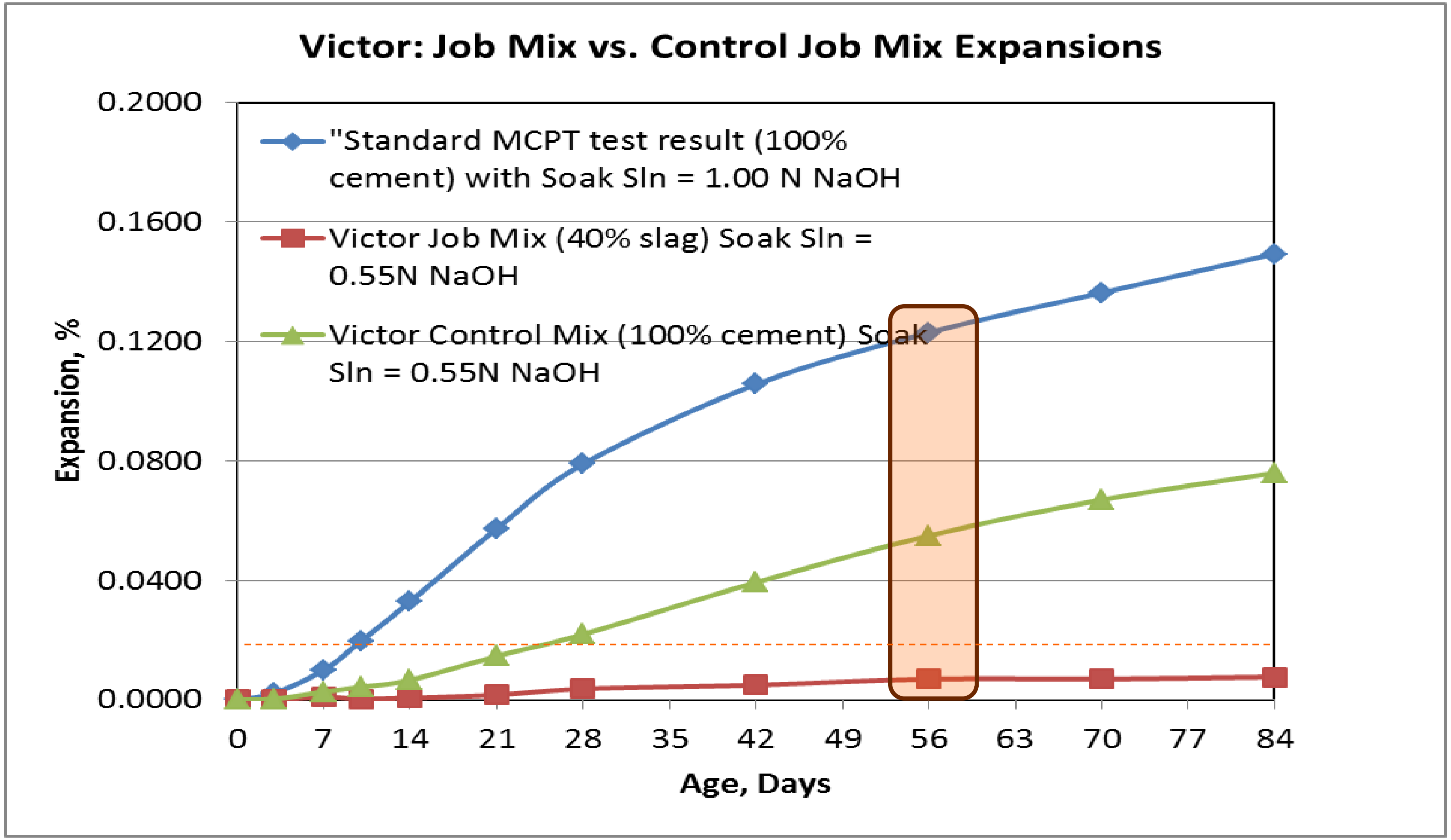
Table 1: Job Concrete Mixture Proportions

Taxiway	Cement Content (lbs/cy)	SCM Content (lbs/cy, Replacement %)	Water-to-Binder Ratio	Coarse Aggregate Content (lbs/cy)	Fine Aggregate Content (lbs/cy)
Tango	549 (Type I) (0.57% $Na_2O_{eq.}$)	99, 15% (Fly ash) (27.22% CaO)	0.41	1840	1153
Victor	381 (Type I) (0.61% $Na_2O_{eq.}$)	254, 40% (Slag)	0.42	1840	1118

MCPT Results for Tango Mixtures



MCPT Results for Victor Mixtures



Summary of Findings

- MCPT is an effective short-term test (56 days) in evaluating ASR mitigation potential of SCMs based on their composition and dosage level.
- A modified MCPT based on some of the significant job mix parameters (w/c ratio, binder composition, binder content) has the potential to capture the influence of job-mix parameters on ASR-induced expansion, and thus determine the ASR potential of job-mix.
- When compared to the expansion of a control mix, the percent reduction in expansion of a job mix can serve as a performance measure for ASR potential of job mixtures.
- Additional work is underway to capture the performance of high-alkali pozzolans and more complex job mix formulations.

Cancer in Concrete (ASR)

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Questions?

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