Are High-Alkali Natural Pozzolans (HANPs) Capable of Mitigating Alkali-Silica Reaction (ASR) in Concrete?

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A Presentation for ACI 123 Session Research in Progress

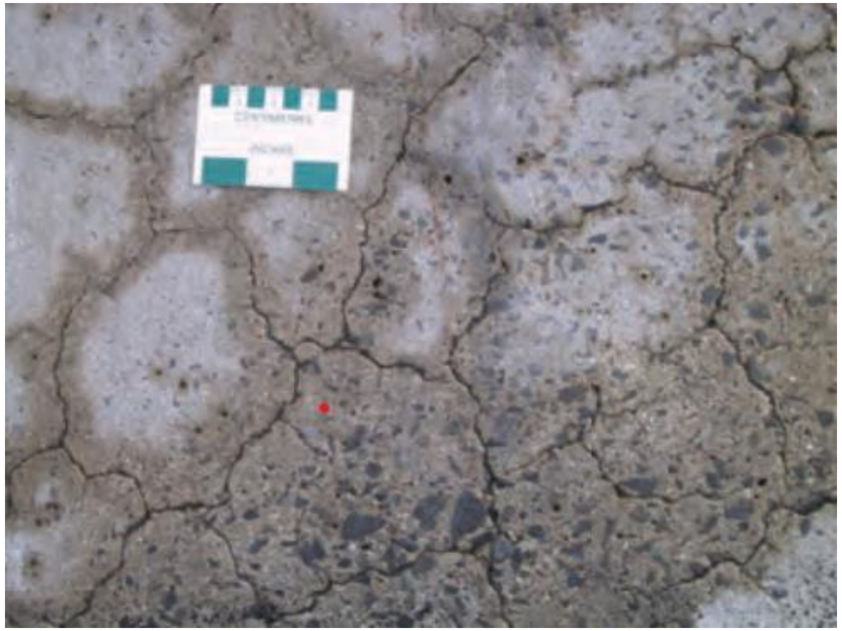
Outlines

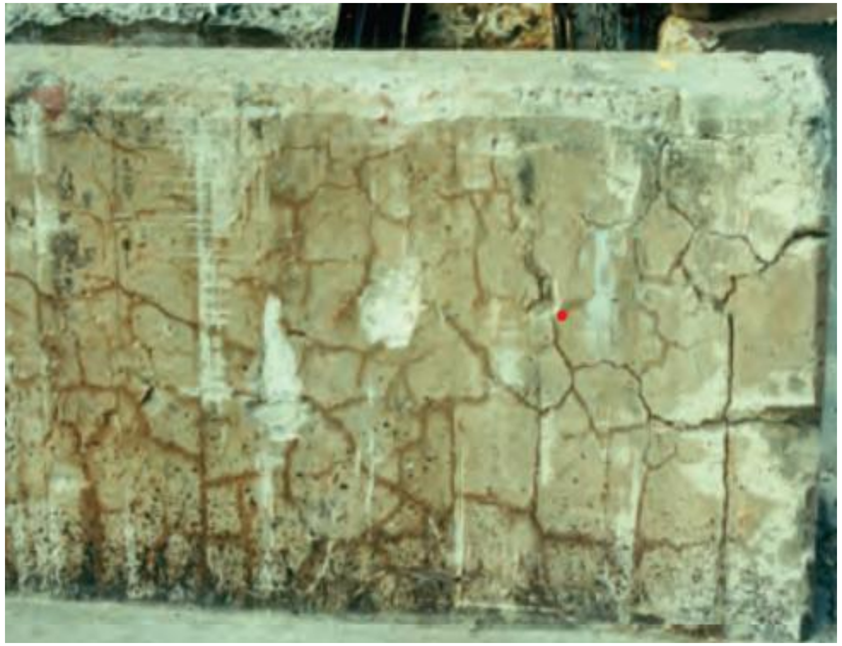
- Introduction
- Experimental Program
- Results and Discussions
- Conclusions
- Future Study

Introduction

What is alkali-silica reaction (ASR)?

Alkali–silica reaction (ASR) is a concrete durability problem that results from deleterious reactions between alkali hydroxides in pore solution of concrete and reactive forms of silica, typically present in aggregates. ASR can result in significant maintenance and reconstruction costs.





https://www.fhwa.dot.gov/pavement/concrete/asr/pubs/hif12022.pdf

Introduction

Role of SCMs in Mitigating ASR

- Role of Supplementary Cementitious Materials in Mitigating ASR
  - Functions
    - Clinker dilution
    - Reduce the permeability
    - Consume CH
    - Alkali-binding and lowering the pH
  - Requirements
    - ASTM C618-19
      - CaO
      - SO_3
      - Moisture content
      - Loss-on-ignition
    - Alkali content Na_2O_e

Introduction

Previously - Reasons why not to use HANPs

- If SCMs contain significant quantities of alkalis which are available in the concrete pore solution, controlling ASR can be very challenging.

Now - Reasons why we should investigate HANPs

- The demand for alternative SCMs in the concrete industry has increased significantly.
- Generally, SCMs with total alkali content in excess of 3 to 4% are considered high-alkali, but not all alkalis are readily available to participate in ASR. It is important to distinguish available alkalis from total alkalis in SCMs.

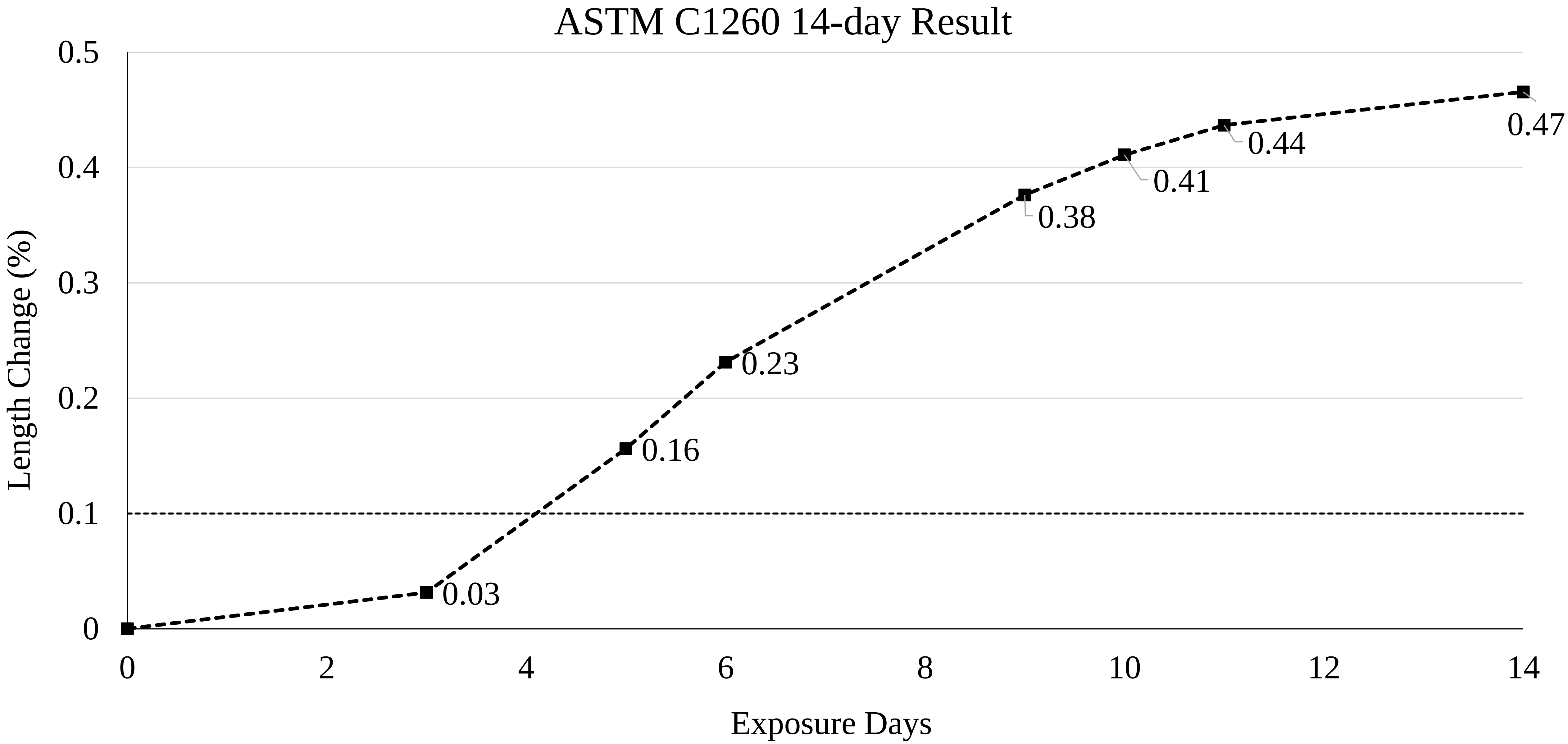
Experimental Program

Methods	ASTM C1567 (AMBT)	ASTM C1293 (CPT)	AASHTO T380 (MCPT)
Duration	14 days	2 years	56 days (or 84 Days)
Sample Size	1 in. ×1 in. ×1.25 in.	3 in. ×3 in. ×11.25 in.	2 in. ×2 in. ×11.25 in.
Materials	Mortar	Concrete	Concrete
Exposure Environment	1 N NaOH Solution, 80°C	100% RH, 38°C	1N NaOH Solution, 60°C
Criteria for Effective ASR Mitigation (With SCMs)	1. Innocuous, <0.10 % at 14-day 2. Potentially Reactive, 0.10% -0.20% at 14 -day 3. Reactive, >0.20 % at 14-day	Effective, < 0.040% at 2-year	1. Effective ≤ 0.020% at 56-day 2. Uncertain 0.020 -0.025% at 56-day 3. Not Effective > 0.025% at 56-day 4. Expansion rate < 0.010% in 2-week between 56-day to 84-day

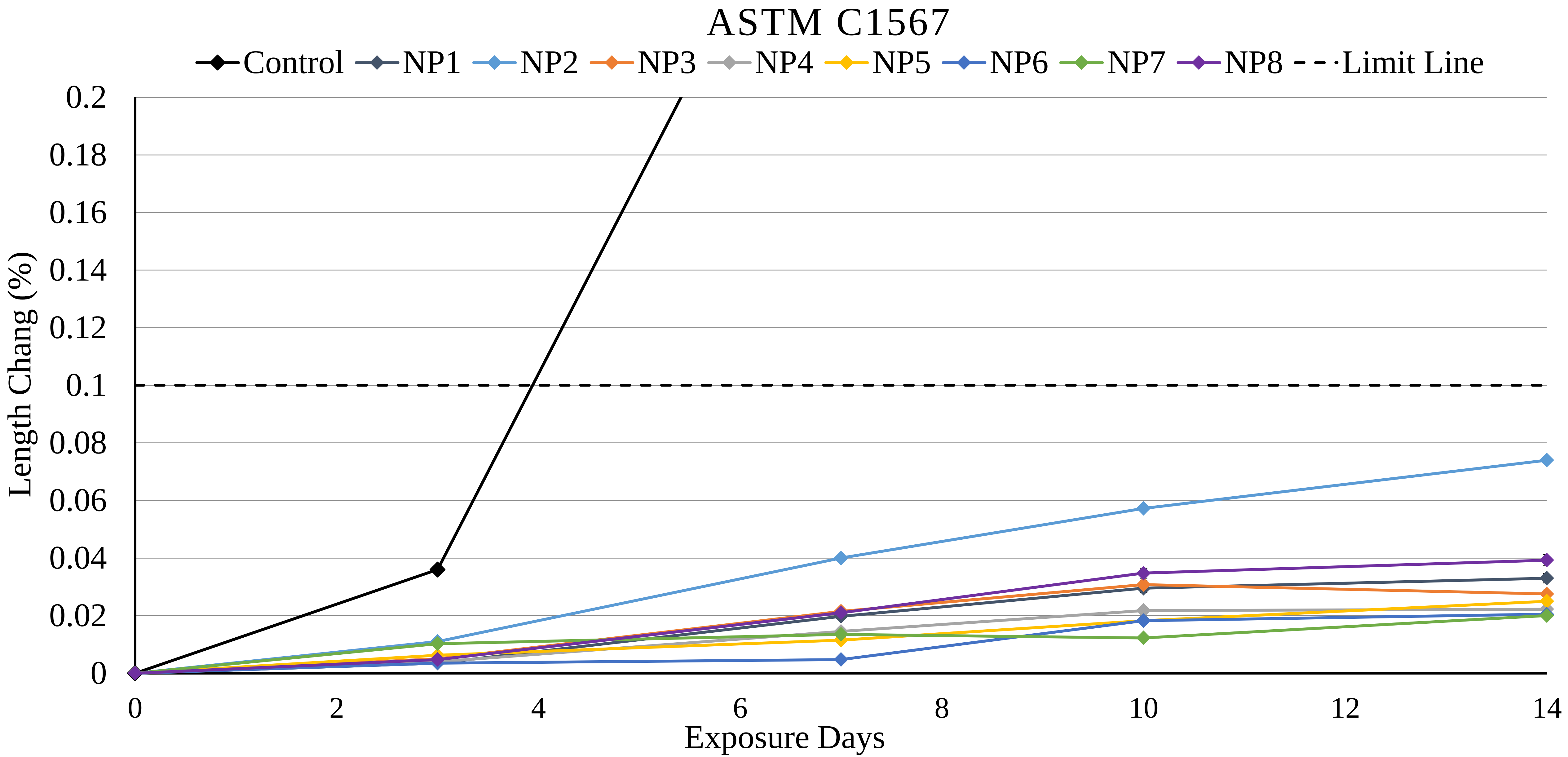
High Alkali Pozzolans

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	TiO_2	**Na_2O_e**	LOI	SG
NP 1	72.73	13.69	1.45	1.83	1.40	0.04	----	**5.24**	4.33	2.53
NP 2 (RFA)	51.98	15.08	5.74	13.43	4.40	0.88	---	**4.74**	0.18	2.56
NP 3	66.90	14.90	4.27	2.16	1.13	---	0.60	**6.85**	---	2.35
NP 4	70.12	12.69	1.83	5.02	0.25	1.46	---	**5.23**	5.43	2.26
NP 5	73.77	12.34	0.95	0.55	0.16	0.01	0.06	**6.86**	3.68	2.35
NP 6	72.11	16.05	0.79	0.76	0.19	0.01	0.07	**7.96**	---	2.40
NP 7	72.39	16.05	0.79	0.88	0.42	0.02	0.15	**7.73**	---	2.34
NP 8 (RFA)	57.59	14.23	2.60	9.73	1.27	6.03	0.4	**6.14**	---	2.42

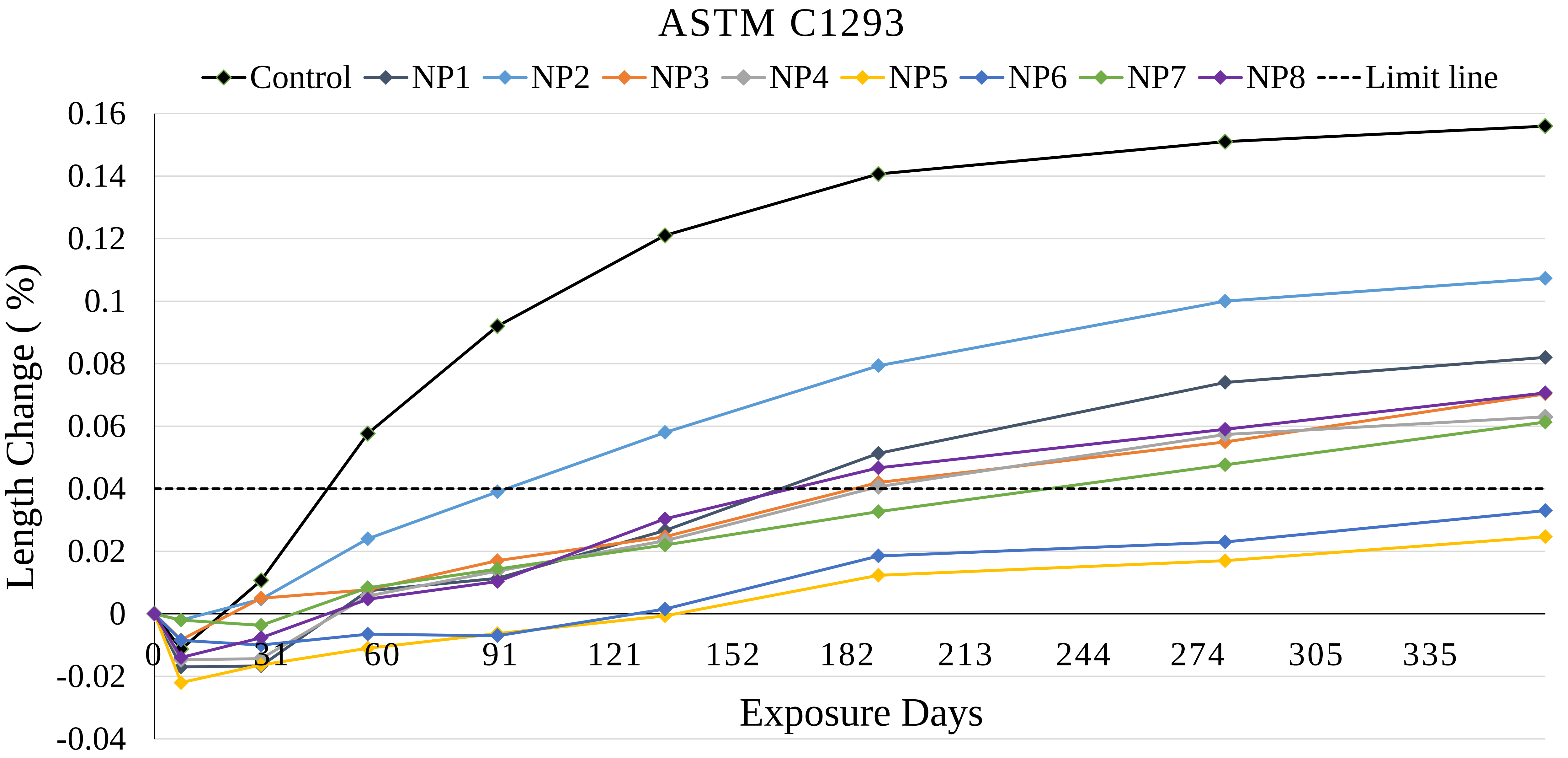
Expansion of Reference Aggregate in ASTM C 1260 Test



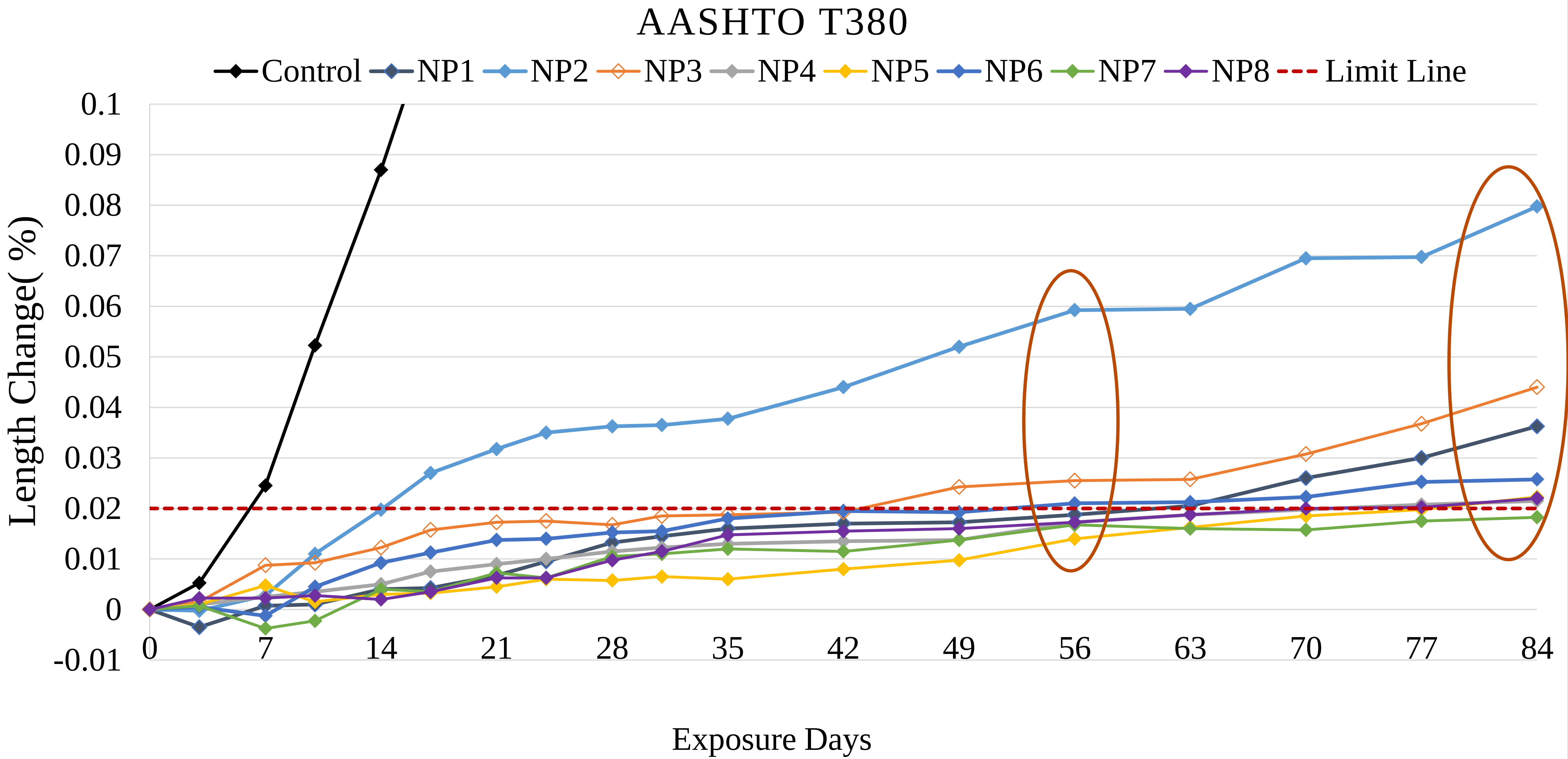
20% Dosage of SCMs ASTM C1567 (AMBT)



20% Dosage of SCMs
ASTM C1293 (CPT - Ongoing)



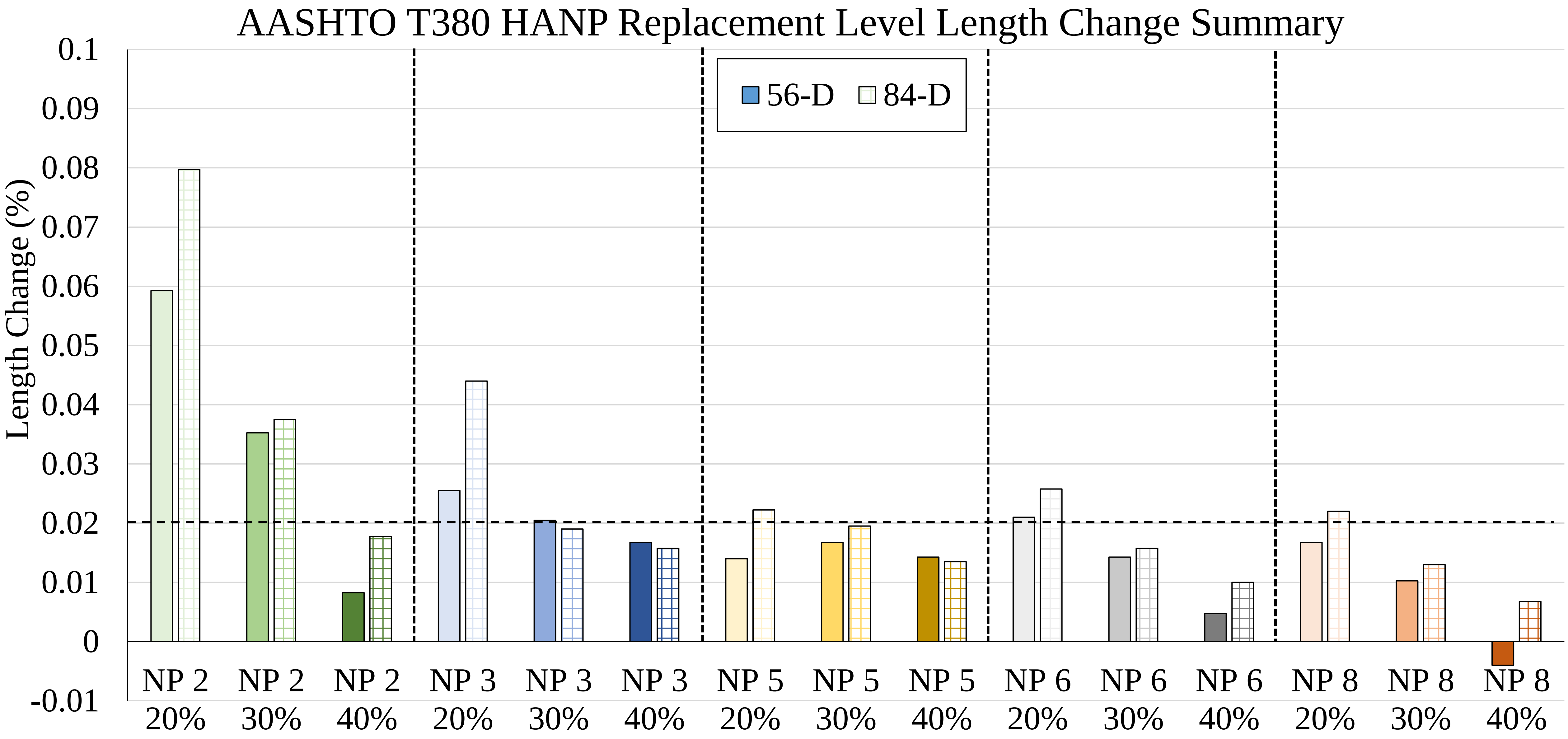
20% Dosage of SCMs AASHTO T380 (MCPT)



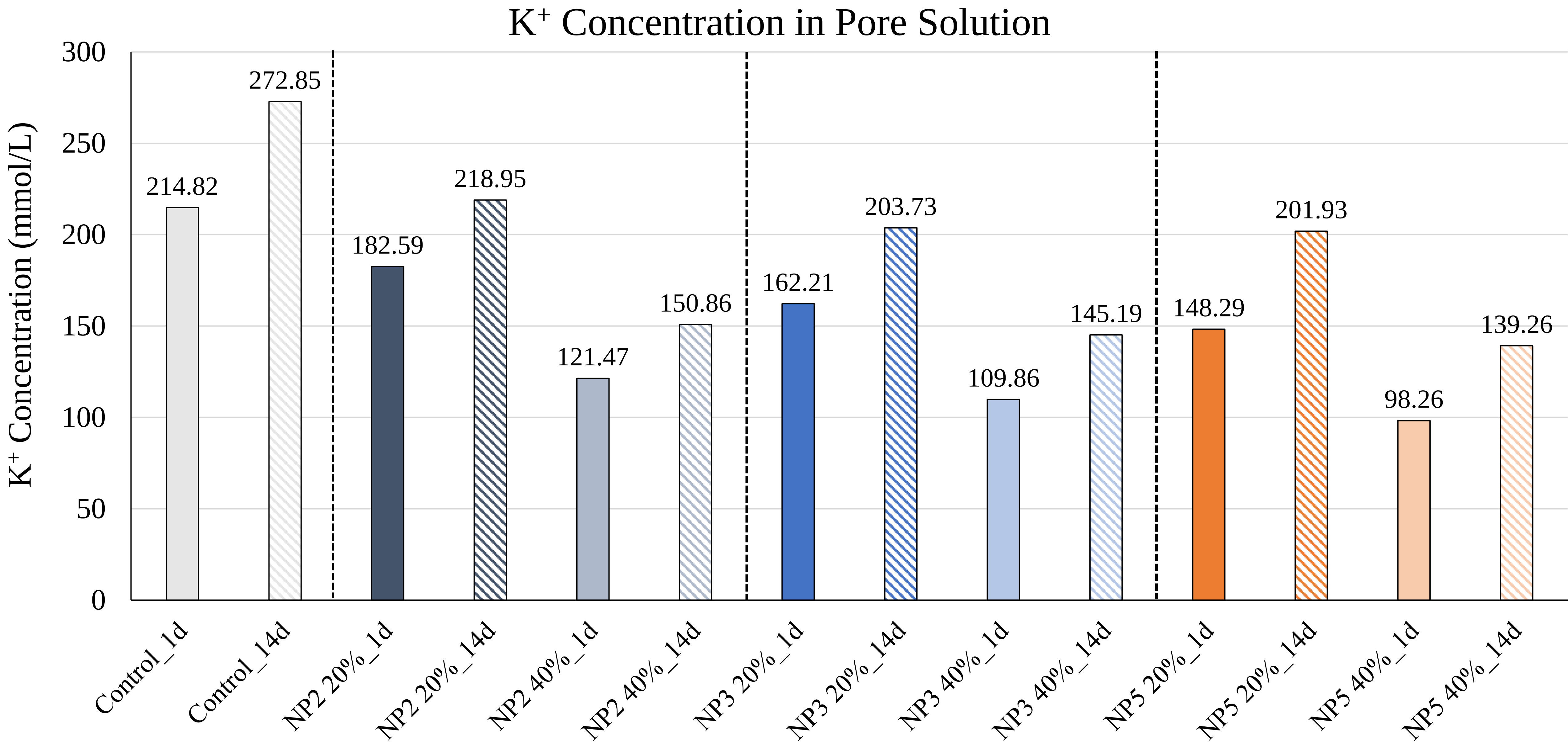
Comparison of Results from Different Test Methods (20% Dosage)

	ASTM C1567 (14-D)		ASTM C1293 (1-Y)		AASHTO T380			
NP Type	Ranking	P or F	Ranking	P or F	Ranking (56-D)	P or F (56-D)	Ranking (84-D)	P or F (84-D)
NP 1	7	P	7	F	5	P	6	F
NP 2	8	P	8	F	8	F	8	F
NP 3	6	P	5	F	7	F	7	F
NP 4	4	P	4	F	3	P	2	P/F
NP 5	5	P	1	Uncertain	1	P	4	P/F
NP 6	3	P	2	Uncertain	6	F	5	P/F
NP 7	1	P	6	F	4	P	1	P
NP 8	2	P	3	F	2	P	3	P/F

AASHTO T380 Replacement Level



Pore Solution Studies on Pastes (On-Going)



Conclusions

- Compared to Control specimens, all the mixtures with HANPs reduce ASR expansion. NP2 (RFA) didn't perform as well as the rest, but reduced ASR induced expansion at 20% replacement level, compared to Control.
- Different test methods yield different characterizations of HANPs. Per ASTM C1567 all the HANPs materials passed the test, but vast majority of HANPs failed in ASTM C1293 (even at 1 year) and AASHTO T380 tests (84 days) at 20% dosage level.
- Preliminary results indicate that at higher replacement levels (30% and 40%) HANPs are performing much more effectively in mitigating ASR.
- Preliminary studies on evolution of pore solution chemistry in these systems support the results from ASTM C1293 and AASHTO T380 tests.

Future Study

- Correlation between total and available alkalis of HANPs, and pore solution chemistry will be studied to develop a basis for evaluating ASR mitigation potential of HANPs.
- Evaluate how the HANPs affect the cement hydration process, e.g. Isothermal calorimetry, setting time, early-age strength gain
- Evaluate the impact of HANPs on other durability considerations.

Acknowledgements

We acknowledge the support of National Pozzolan Association (NPA),and its member companies for providing the materials for this study.

Thanks for Listening

Any Questions?