ASR Resistance of Ground Bottom Ash-Based Alkali-Activated Concrete and the Prospect of Using MCPT for the Evaluation

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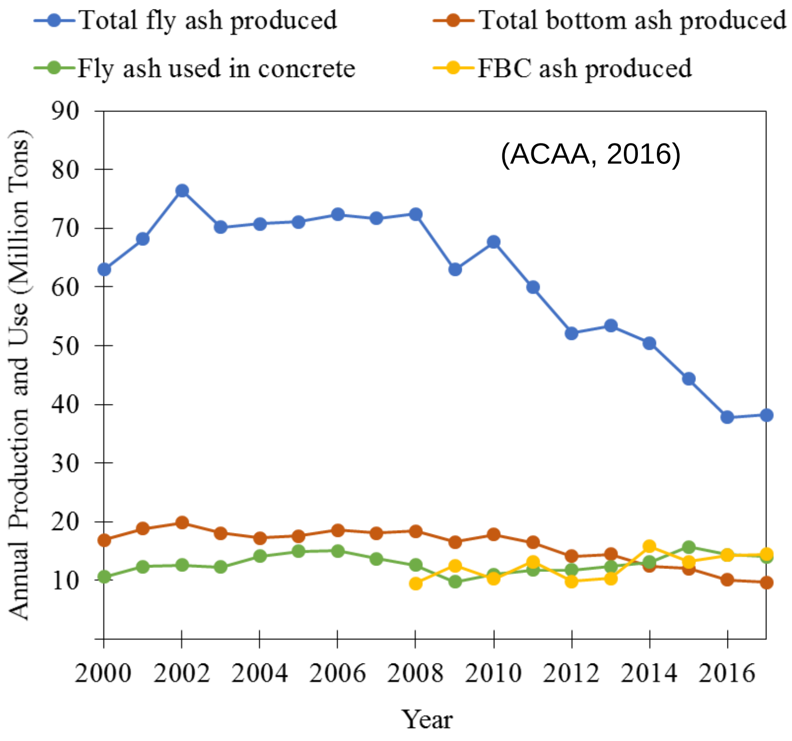
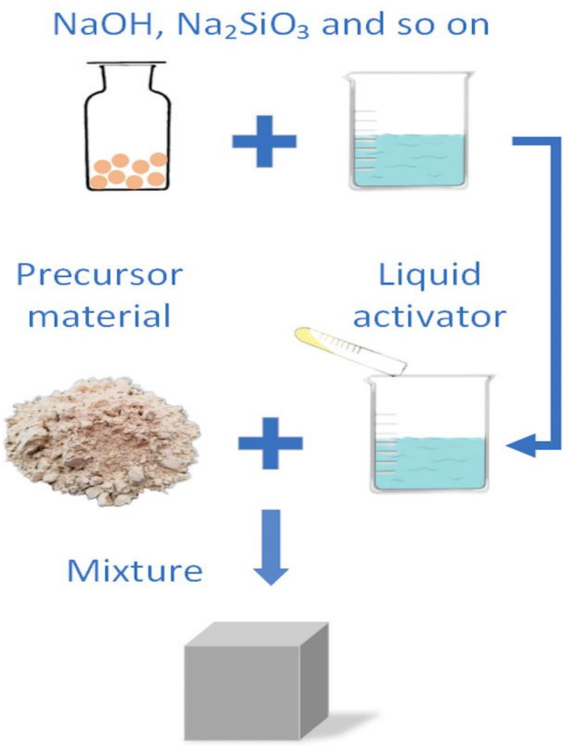
Background & Motivation

- By 2025, global cement demand - 4.7 billion metric tons (an increase of 2.9% per year).
- Eco-efficient binders –Alkali-activated materials
- Fly ash and GGBS – popular precursors
- Rapid decommissioning of thermal power plants in and competitive use of Slag as SCMs.
- Ground bottom ashes - emerging unconventional precursor for Alkali activated systems.

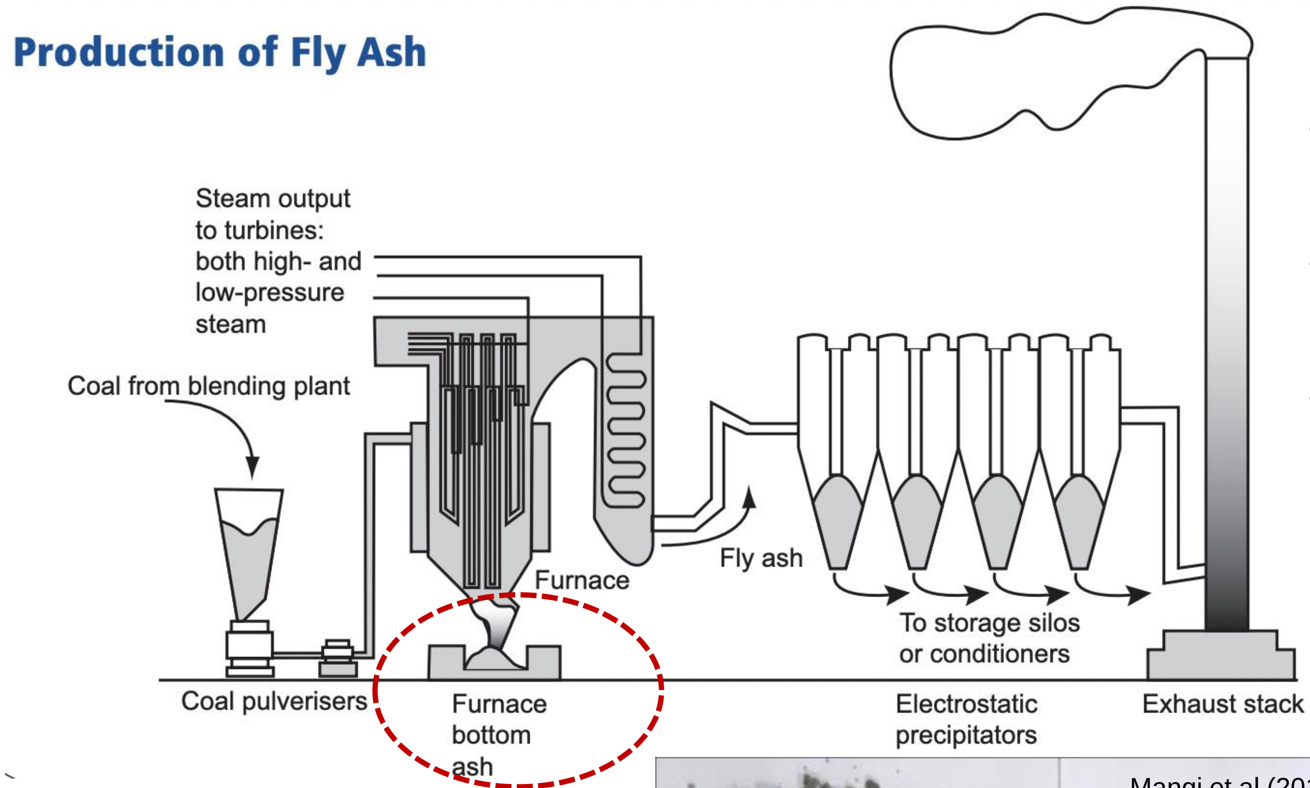




Alkali Activated concrete

Qin et al (2022)

Ground Bottom Ash



Andrabi (2007)

Mangi et al (2019)

- Similar chemistry to Fly Ash
- Potential SCM
- Coarser particle size than FA

Background – ASR in AACs

- Concern on ASR Susceptibility in Alkali activated system

The high alkalinity of pore solution

- Deleterious ASR may be unlikely to occur as

the reaction products in alkali-activated concrete typically contain no/limited calcium hydroxide (CH)

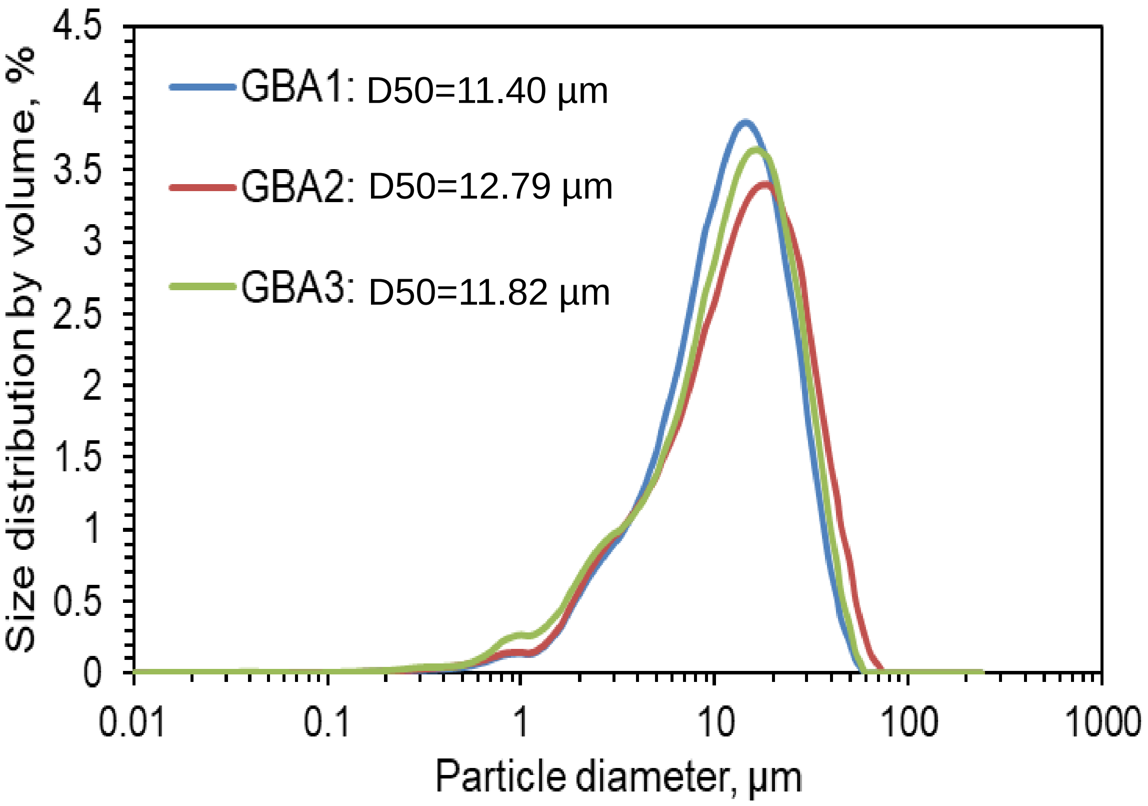
- Literature mainly reports the ASR resistance behavior of alkali-activated fly ash and slag systems.

- The realm of ASR-related performance for unconventional precursors is largely unexplored.

Objective
ASR resistance in GBAs-based AAC using MCPT

Materials - Binders

Oxide (%)	GBA1	GBA2	GBA3
SiO_2	47.6	57	42.9
Al_2O_3	20.07	17.89	16.62
Fe_2O_3	24.12	5.84	7.46
CaO	2.82	11.5	23
SO_3	0.08	1.23	0.38
Na_2Oeq	2.01	0.97	1.29
LOI (<spec. 6% ash to 10%NP)	1.08	0.01	1.37



Augite	-	-	3.4%
Amorphous	**77.1%**	**67.3%**	**52.7%**

Materials

Material	Binder Composition	Activator Solution		
		Na2O (% by mass of binder)	Silica Modulus	Solution / binder
AAC 1	GBA1 + 3% CH	9.25	1.25	0.6
AAC2	GBA2 + 3% CH	9.25	1.25	0.6
AAC3	GBA3 + 3% CH	9.25	1.25	0.6

3 types of reactive aggregates are considered (classified using C1778 on basis of C1260 results)

a) Roaring Spring sand – R1 (moderately reactive)
b) Spratt limestone – R2 (high reactive)
c) Jobe Sand – R3 (very high reactive)

Normal river sand (R0) and limestone CA : to establish control specimens

Experimental - MCPT

- AASHTO T 380 -19
- Less effort in processing aggregates required
- Shorter / rapid test with a duration of 56 days (majority of aggregates).
- Used for evaluating Aggregate reactivity and efficiency of SCMs in mitigating ASR.
- Subjected to :1 N NaOH solution and 60°C
- Non-reactive sand is used for reactive CA and vice versa
- 2”x2”x11” specimens

Expansion at 56 days (με)	Efficiency of mitigation
<200	Effective
200 -250	Uncertain
>250	Ineffective

Scope Matrix

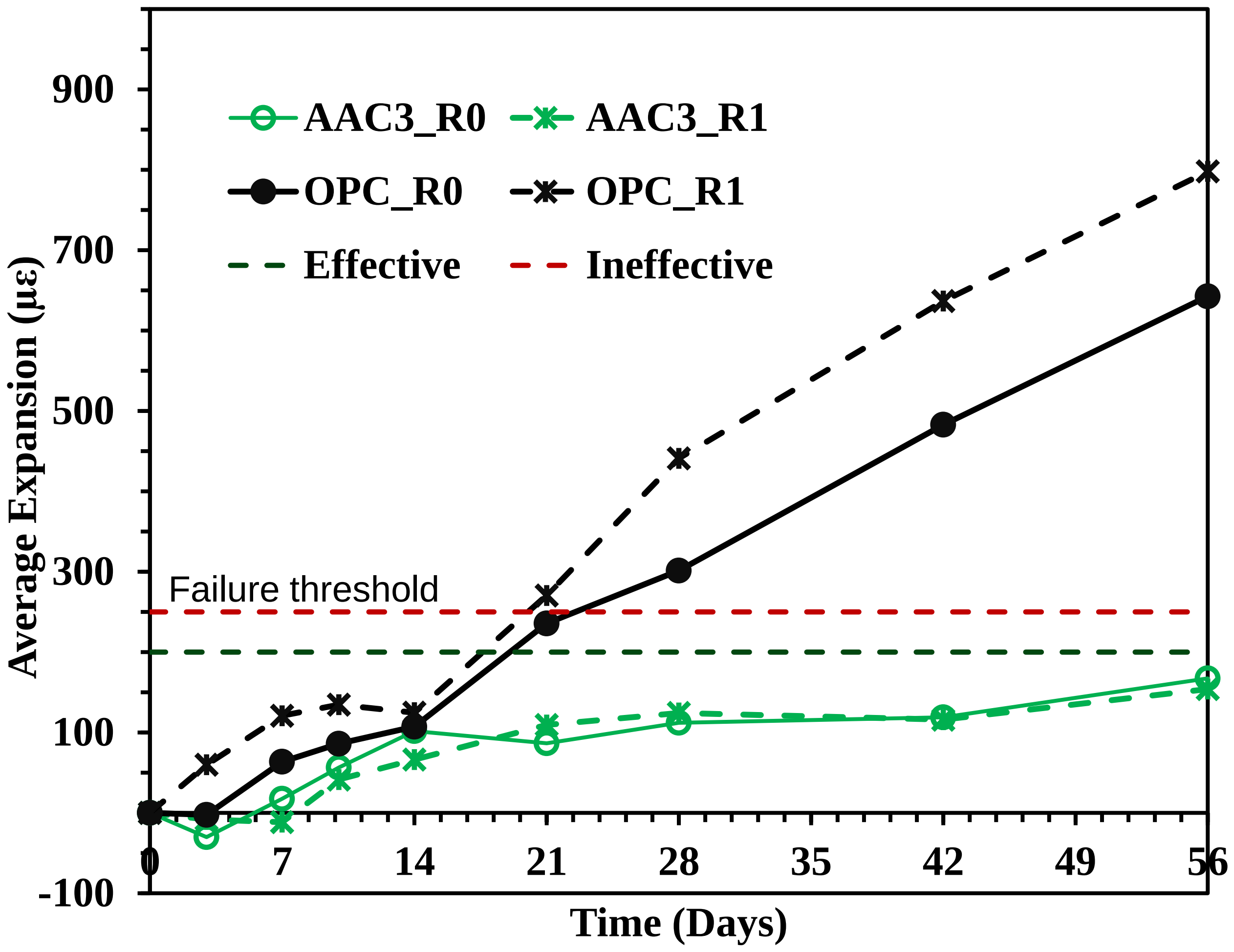
Mixes	s/b	Binder (kg/m^3)	Activator (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Water (kg/m^3)
AAC1	0.6	480	288	824	1052	16
AAC2	0.6		288	852	1088	16
AAC3	0.6		288	813	1035	16

Concrete mix proportions:
35% paste volume
Fine aggregate (FA) / Total aggregate (TA) = 0.45 by volume
Compressive strength > 40 MPA

- OPC control specimens - MCPT recommendations- w/c=0.45 in combination with all tested aggregate categories.

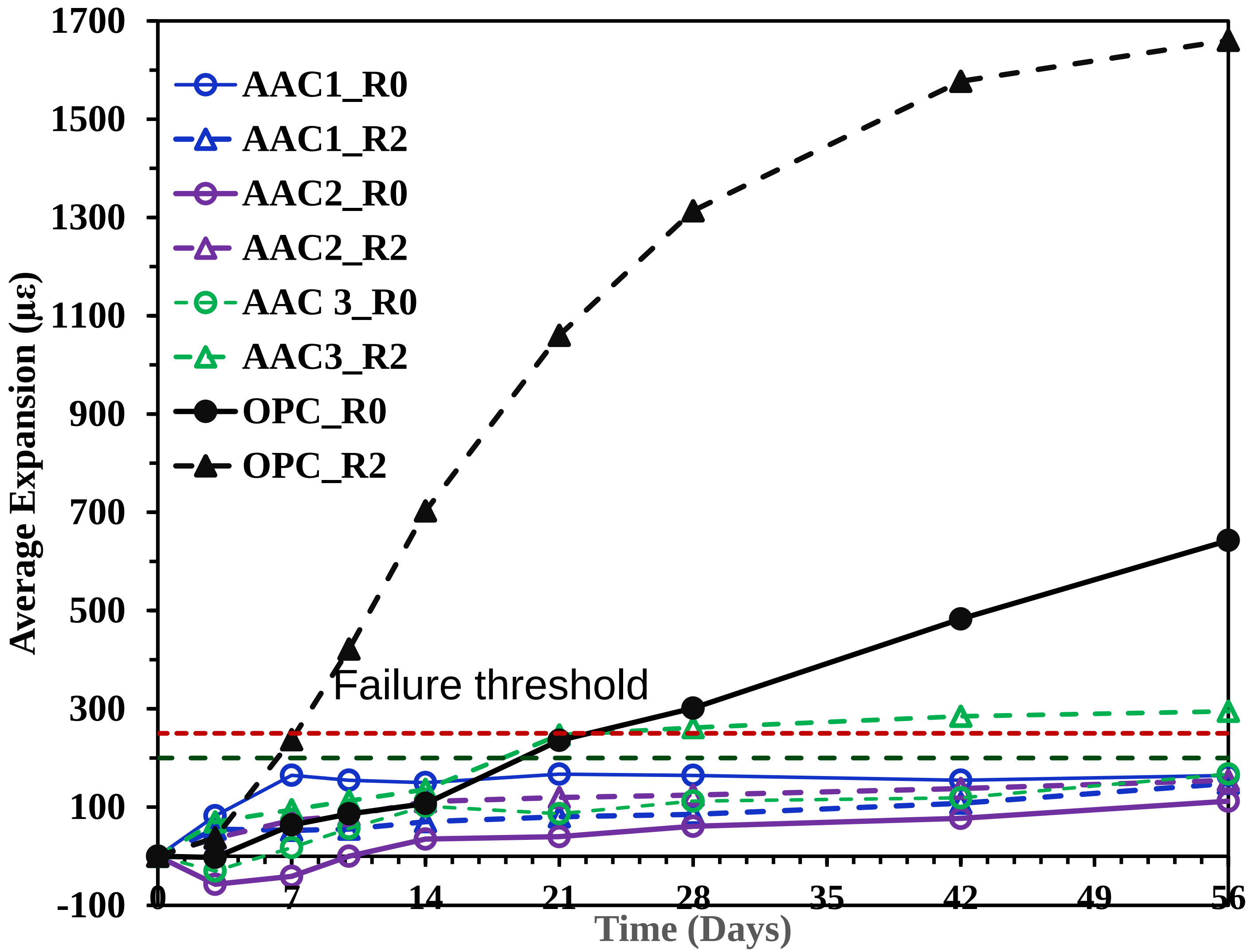
Mixes	R0	R1	R2	R3
AAC1	✓	–	✓	–
AAC2	✓	–	✓	–
AAC3	✓	✓	✓	✓
OPC	✓	✓	✓	✓

Results: Moderately reactive aggregates



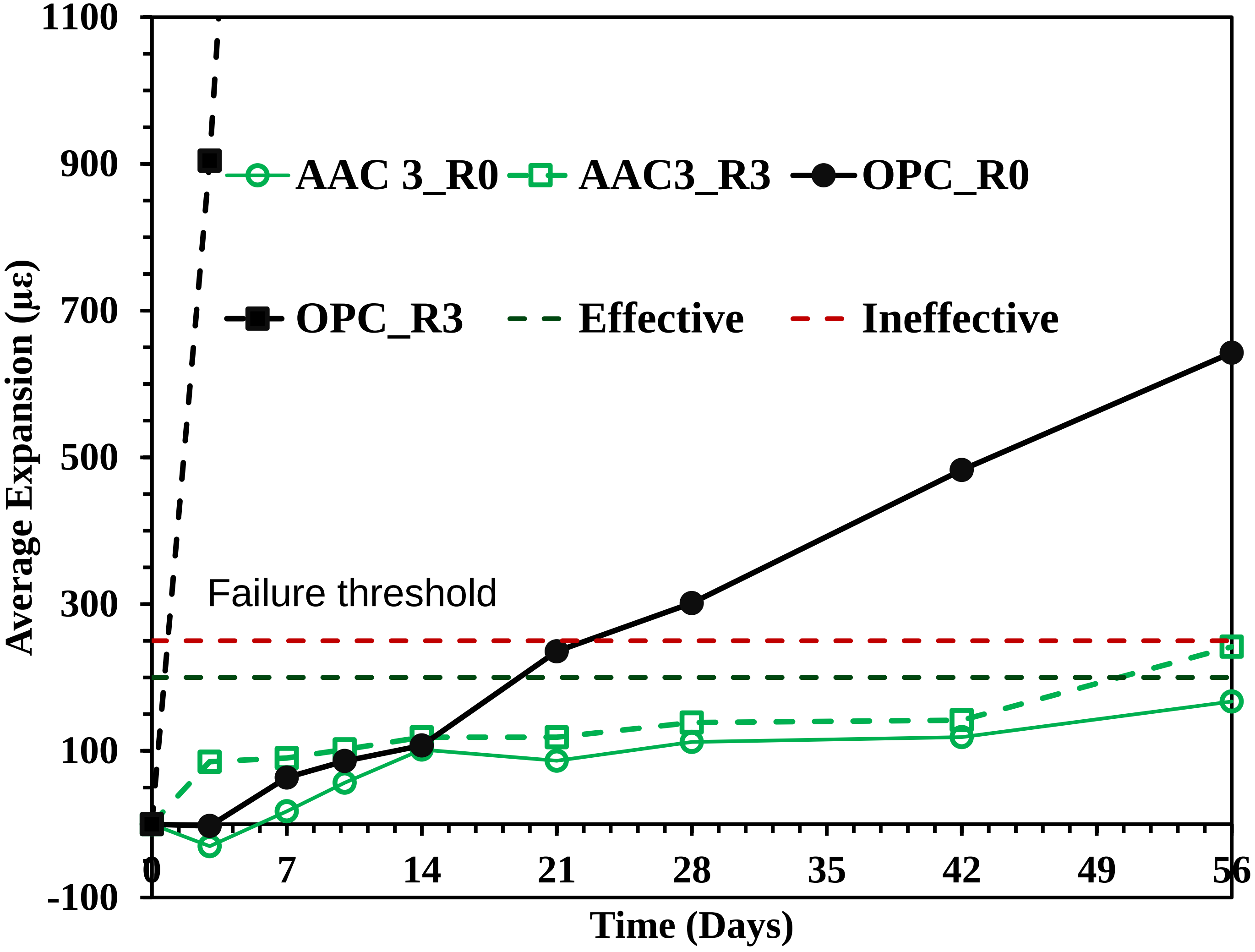
- AAC specimens demonstrate superior resistance.
- AACs, perform similarly in the presence and absence of moderately reactive aggregates.

Results: Highly reactive aggregate



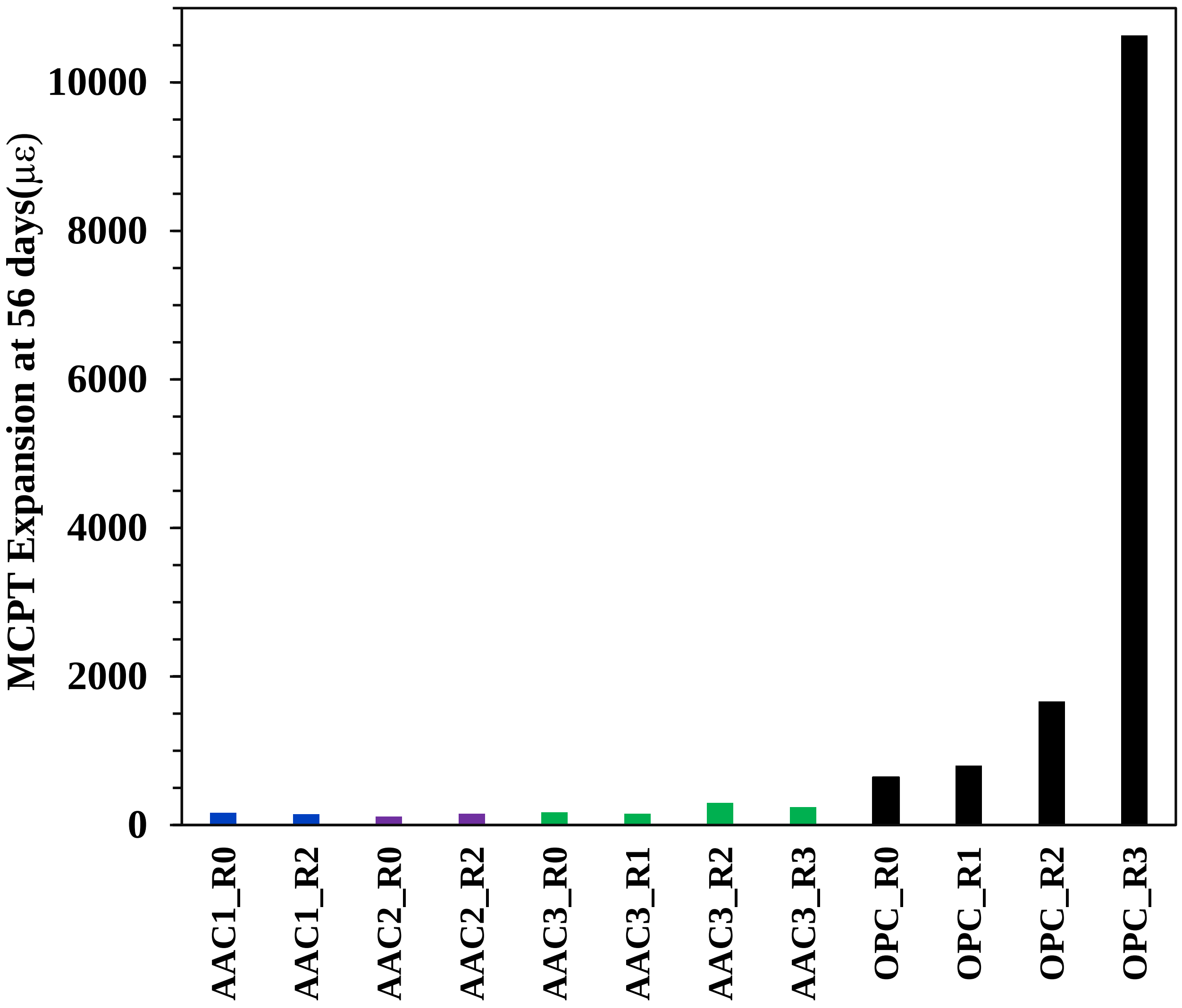
- AAC specimens : significantly low levels of expansion
- Potentially due to alkali binding, low availability of calcium and improved microstructure

Results: Very high reactive Sand



- OPC with R3: very high expansion in order of 10,000 με.
- Nothing alarming for AAC despite high solution/ binder ratio.

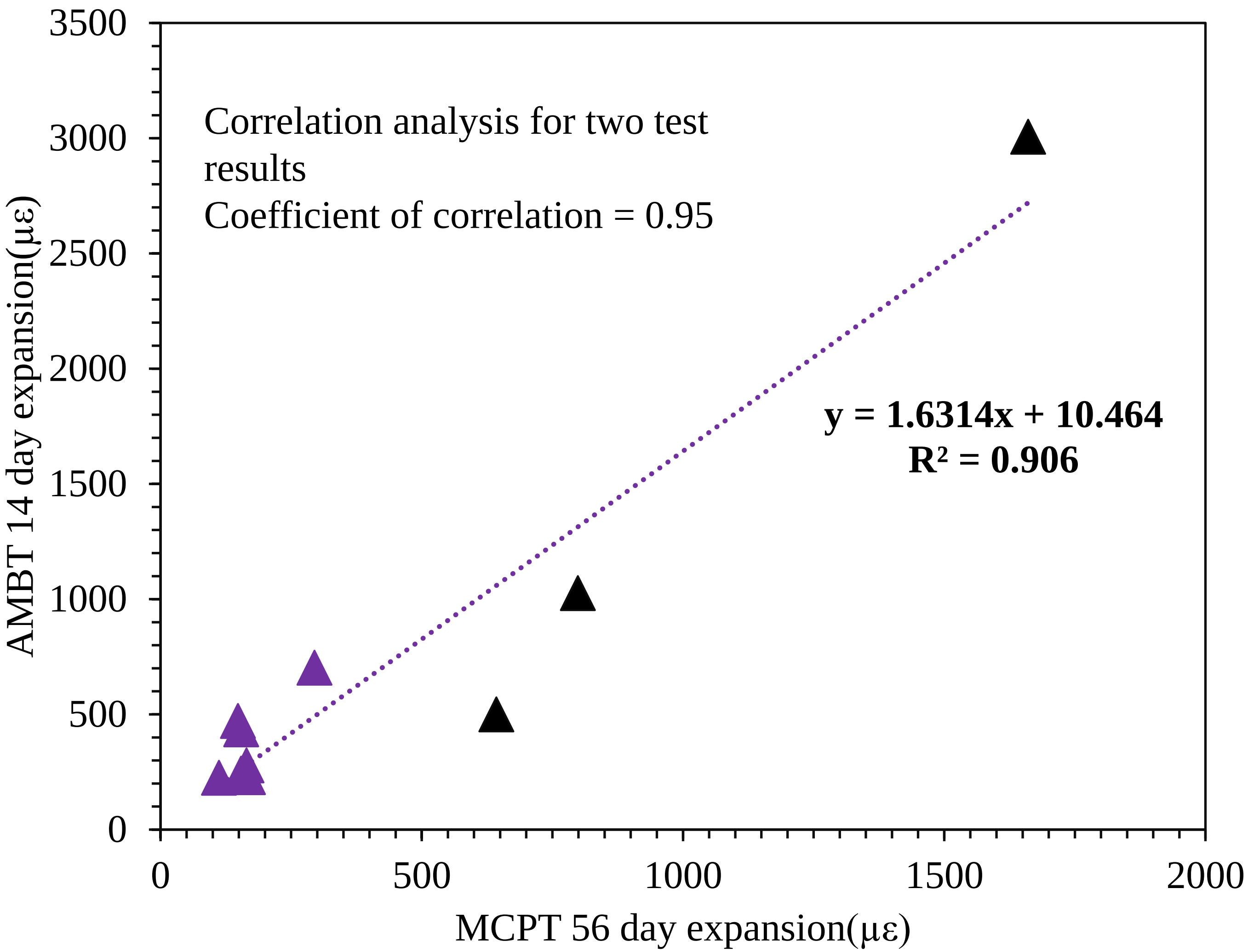
Comparison of performance



$$\text{ASR Susceptibility Index} = \frac{\text{OPC Expansion at 56 days}}{\text{AAC Expansion at 56 days}}$$

For moderately reactive (R1) type aggregate	
AAC3	5
For highly reactive (R2) type aggregate	
AAC1	11
AAC2	11
AAC3	6
For very highly reactive (R3) type aggregate	
AAC3	44

MCPT vs. AMBT



- The results obtained from 56 days of MCPT demonstrate a strong correlation with the 14-day expansions of AMBT.
- Both test methods indicate that AACs exhibit a high level of resistance to expansion induced by ASR

Summary and Future Works

- All the tested AACs demonstrated superior resistance to ASR.
- Potentially due to alkali binding, low levels of calcium, and refined pore structure
- Conventional concrete expanded evidently in presence of reactive aggregates due to expansive ASR gel.
- AACs can be potentially used as an ASR mitigation strategy in locations constrained to reactive aggregates.
- MCPT even though with a conservative threshold apparently suits the context of predicting ASR-related deterioration for GBA-based AACs.
- No visible signs of distress were noted for AACs.

Future Works

- Correlating the pore solution chemistry of AACs to ASR resistance.
- Relation of surface and bulk electrical resistivity with the ASR behavior of AACs.

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