Glass Pozzolan Technical Data, Introduction

Extensive test data has been generated for glass pozzolan performance required by the ASTM C1866 Standard.

First, the chemistry of glass pozzolans is very consistent across North America and the pozzolans are required to be 99.5% pure glass. Given that exceptional consistency, the focus of the test data is to compare the two classifications of glass with each other and fly ash; to determine the effect of pozzolan particle size on performance, and to determine the optimum cement replacement levels.

The durability data is based on Spratt and Placitas aggregates over a wide spectrum of test methods, including ASTM C1293, ASTM C441, and AASHTO TP110.

Further, test data on chloride ion permeability and sulfate resistance is included.

Strength Activity Index (SAI) of Glass Pozzolans

A historical measure of pozzolan reactivity has been the strength activity index (SAI). This test measures whether the pozzolan adds compressive strength to the concrete compound versus a control mix design without the pozzolan.

At ASTM, there are efforts underway to replace this test with other indicia, such as calcium hydroxide content, LOI, resistivity, and others, so the measurement of pozzolanic reaction is evolving.

The new ASTM standard for glass pozzolans calls for an SAI of 75% of control at 7 days and 85% of control at 28 days. The ASTM C618 standard for fly ash and natural pozzolans calls for 75% of control at 7 days or 75 % of control at 28 days, a much lower standard than glass.

Figure 1

Type GE Glass: Strength development and strength activity index (SAI) for different finenesses (d50 3-8 μm)

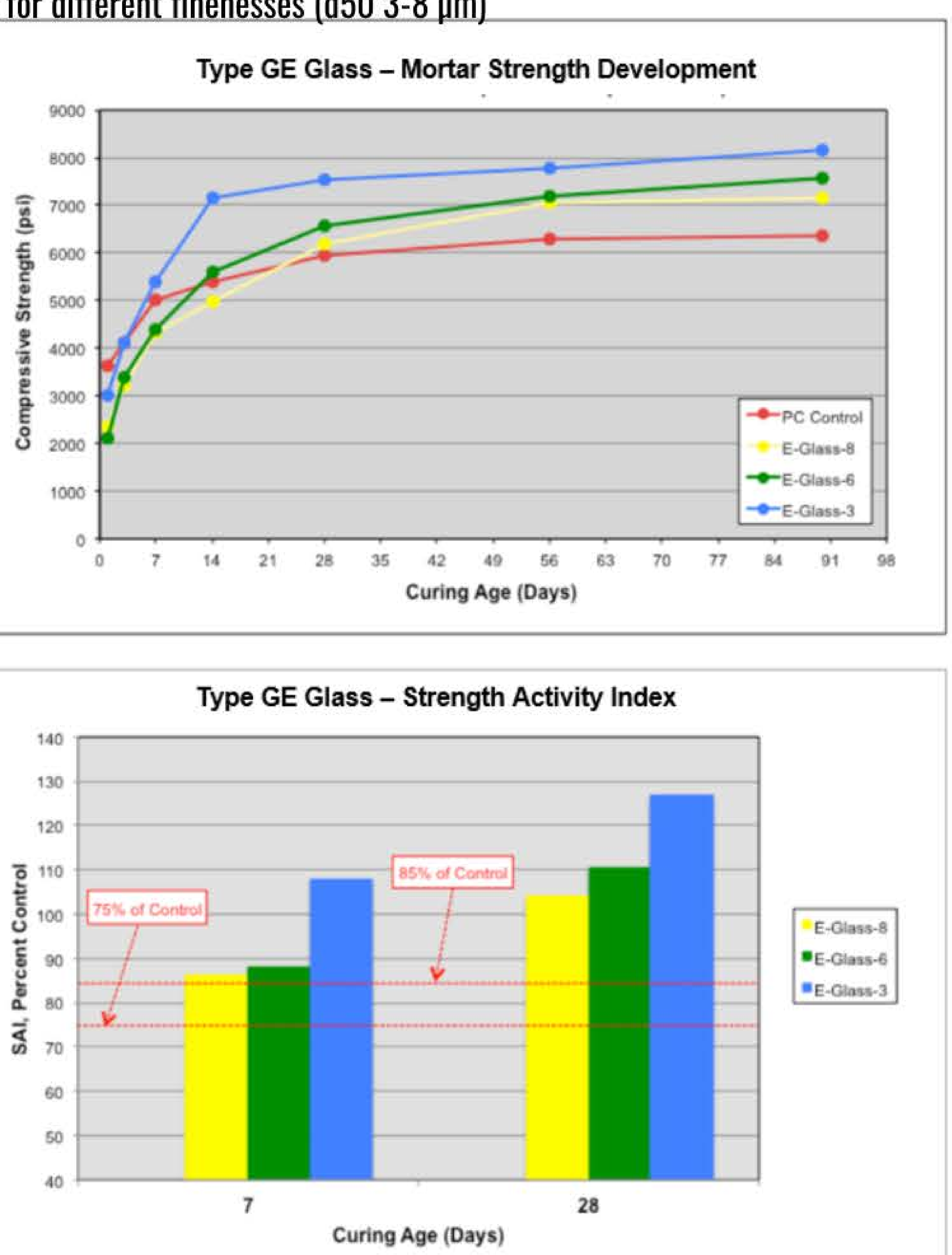
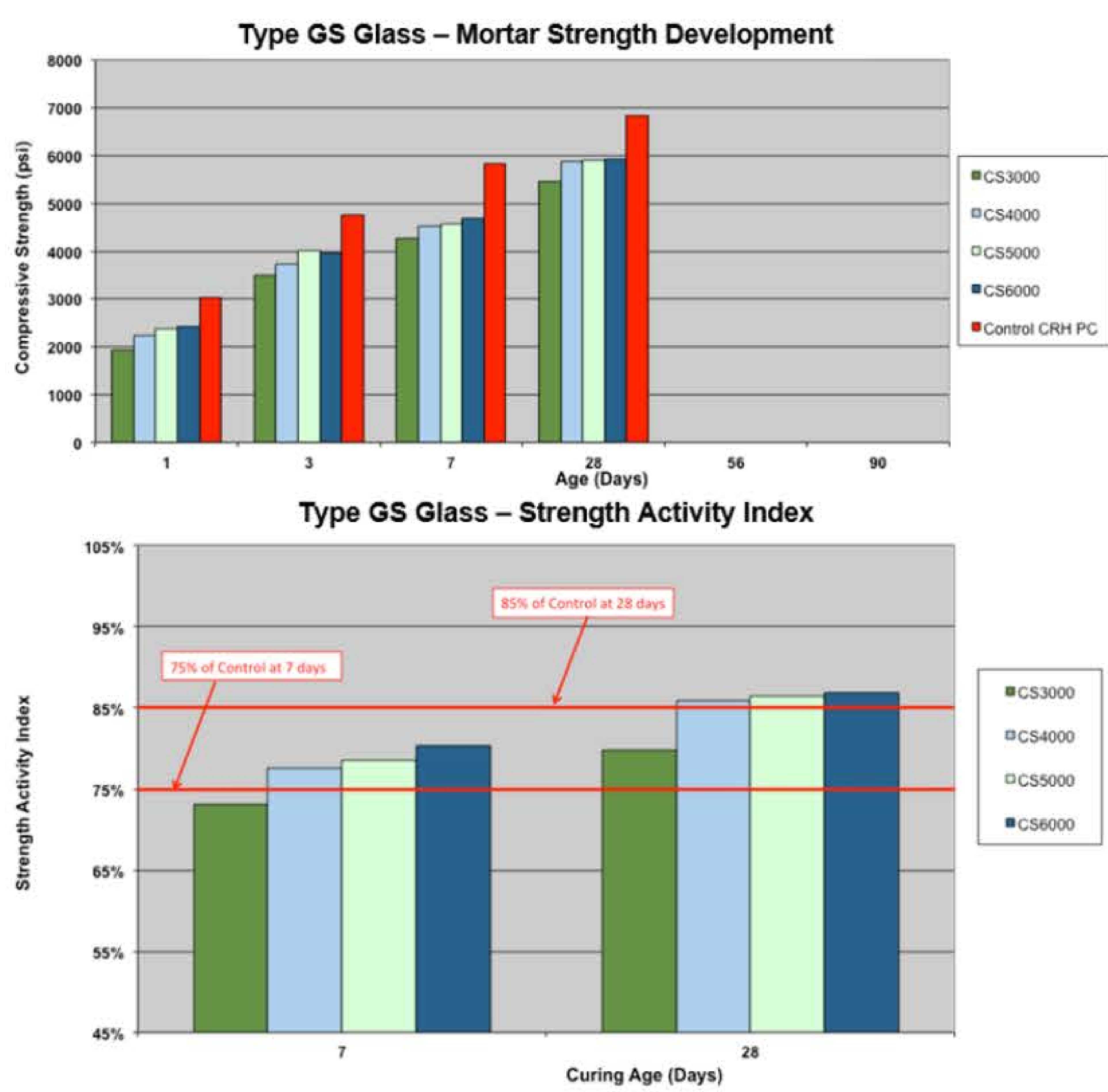


Figure 2

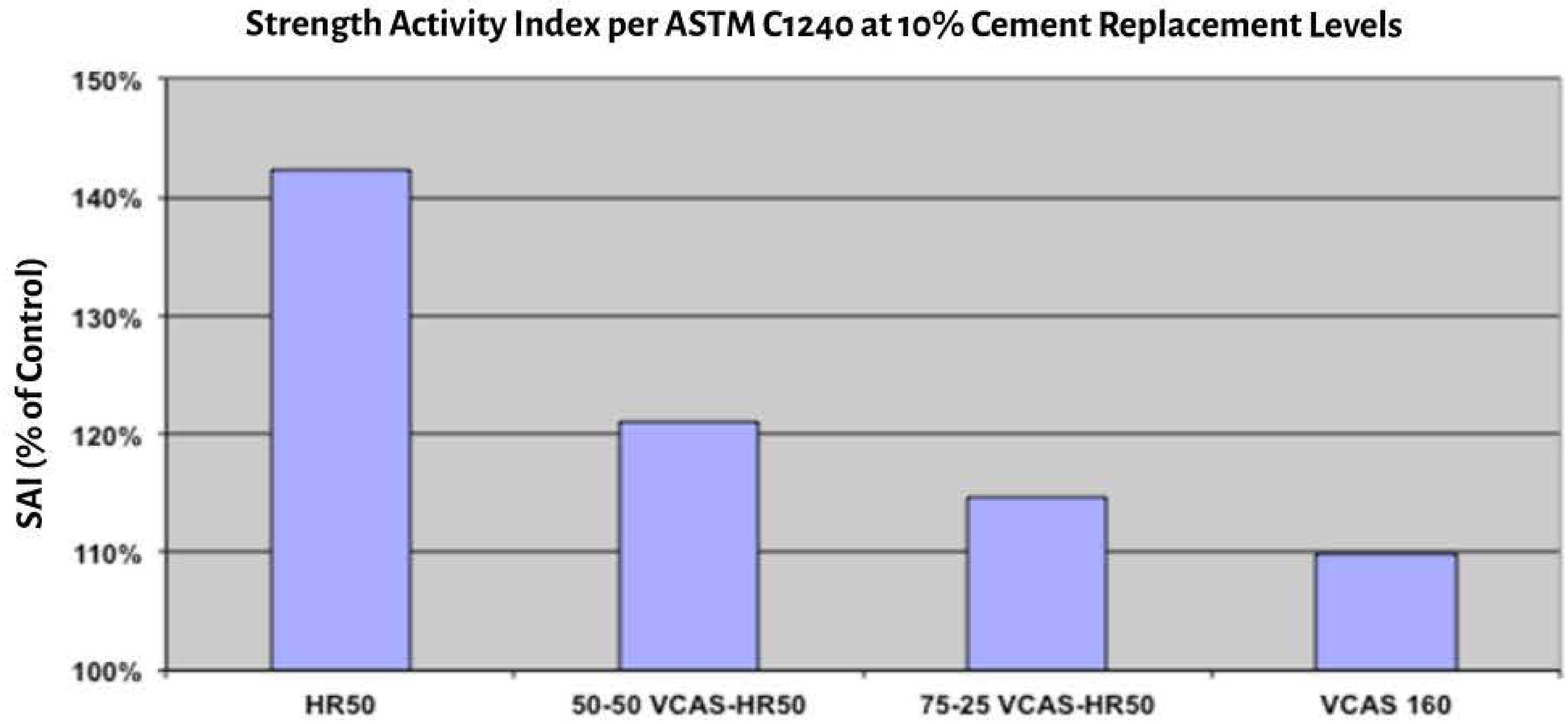
Type GS Glass: Strength development and strength activity index (SAI) for different Blaine finenesses (3,000-6,000 cm2/g)

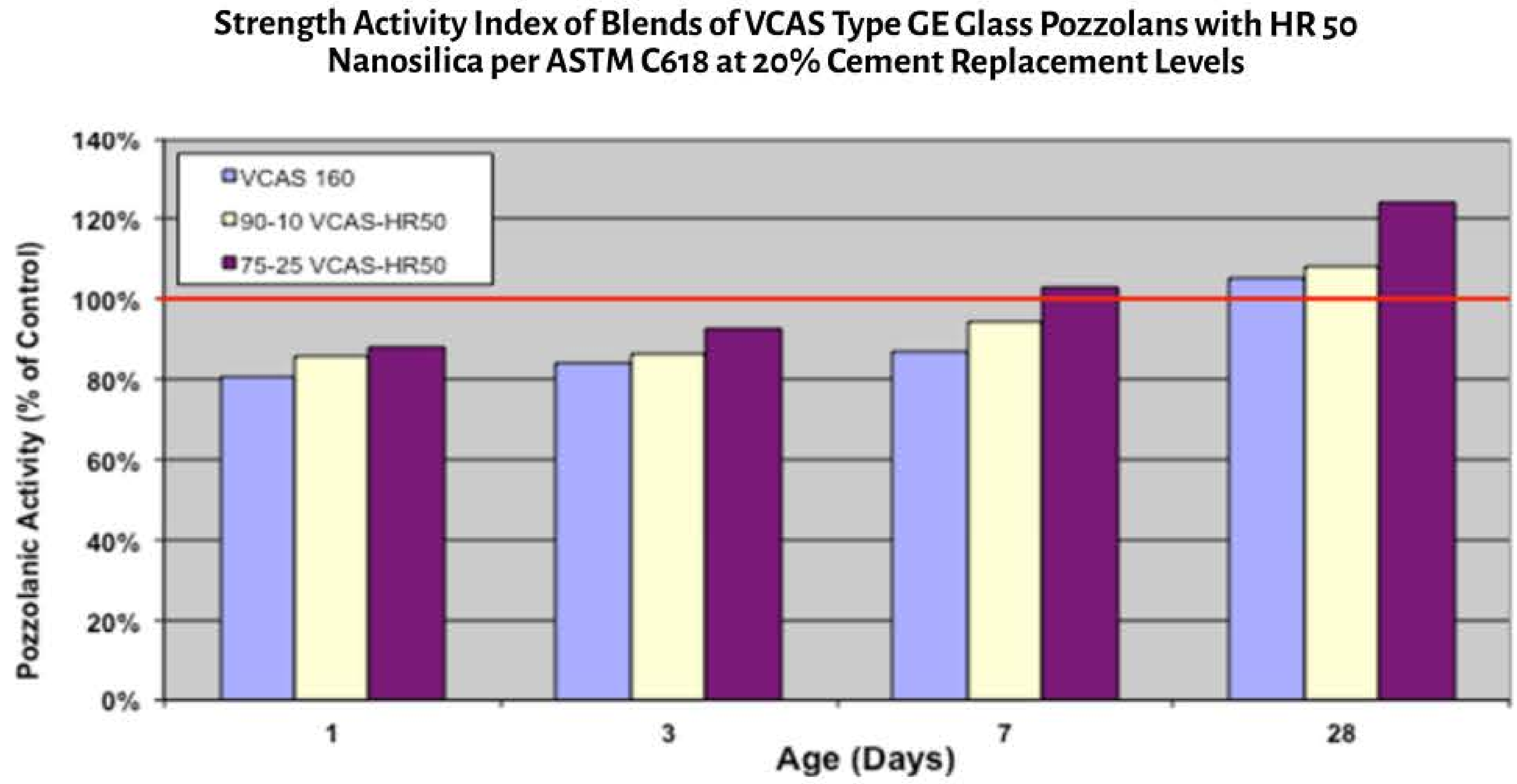


Both Type GE and GS pozzolans show excellent pozzolanic properties.
The main differences are ASR mitigation and impact on concrete color.

Figure 3

Strength Development- HR50 Nanosilica Blended with Type GE Glass Pozzolans



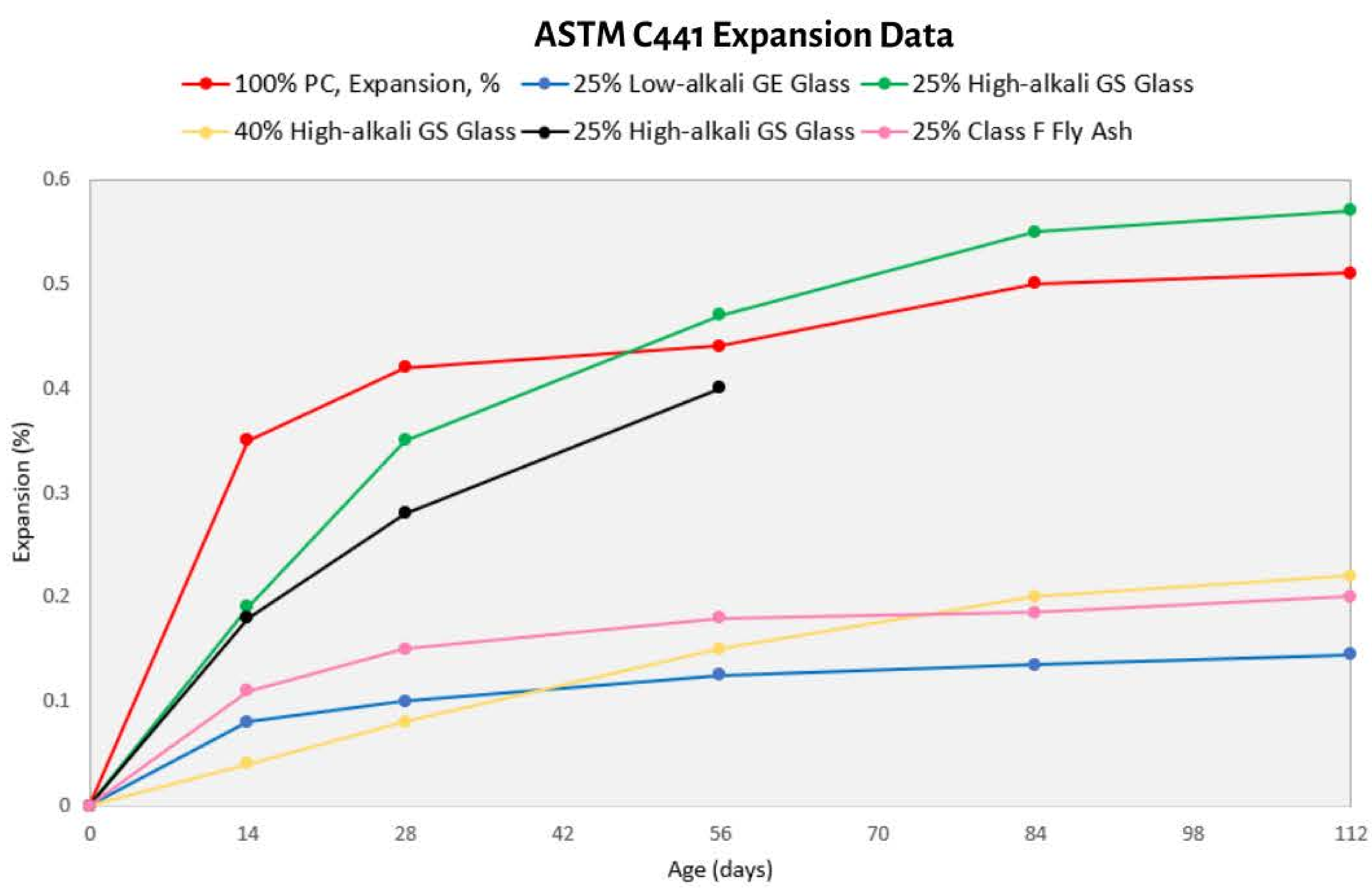


Different blend ratios of HR 50 Nanosilica and Type GE pozzolans all show greater than 110% strength activity index when tested according to ASTM C1240, the silica fume standard at 10% cement replacement.

Early strength can be enhanced by blending VCAS Type GE pozzolans with Nanosilica.

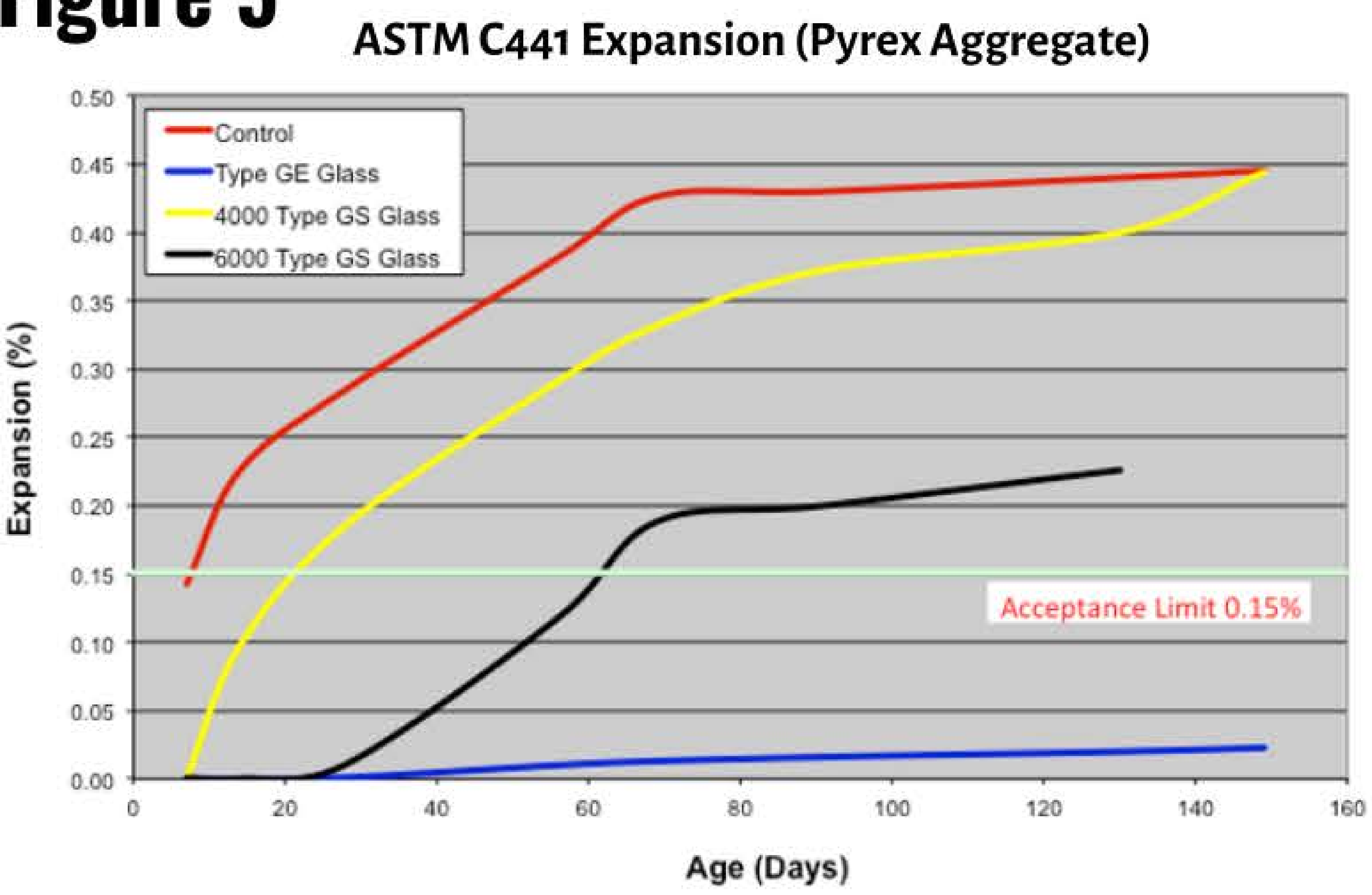
Figure 4

Expansion data for ground pozzolans, Type GS (High Alkali) vs. Type GE (Low Alkali) vs. Class F Fly Ash. Courtesy of Mahipal 2019.



ASTM C441 is an excellent screening tool to determine how different types of pozzolans and dosages will affect expansion in concrete. Type GS pozzolans have minimal impact on reducing expansion caused by reactive aggregates. Type GE VCAS pozzolans effectively mitigate ASR from any reactive aggregate.

Figure 5



Comparison of ASTM C441 expansion data for mortars prepared with Pyrex aggregate and 20% cement replacement with glass pozzolans: Type GE Glass; Type GS Glass (4,000 cm2/g); and Type GS Glass (6,000 cm2/g). Finer particle sizes are more effective at reducing expansion.

Figure 6

Influence of Type GE Pozzolans Dosage on Concrete Prism Expansion Containing Reactive Las Placitas Gravel Aggregate in CPT (ASTM C1293). Courtesy of Thomas et al.

ASTM C1293 is a standard test to measure expansion in concrete prisms. Comparisons of GE Glass, GS Glass, and Fly Ash cement replacement are consistent with ASTM C441 data. Type GE glass is very effective for ASR mitigation.

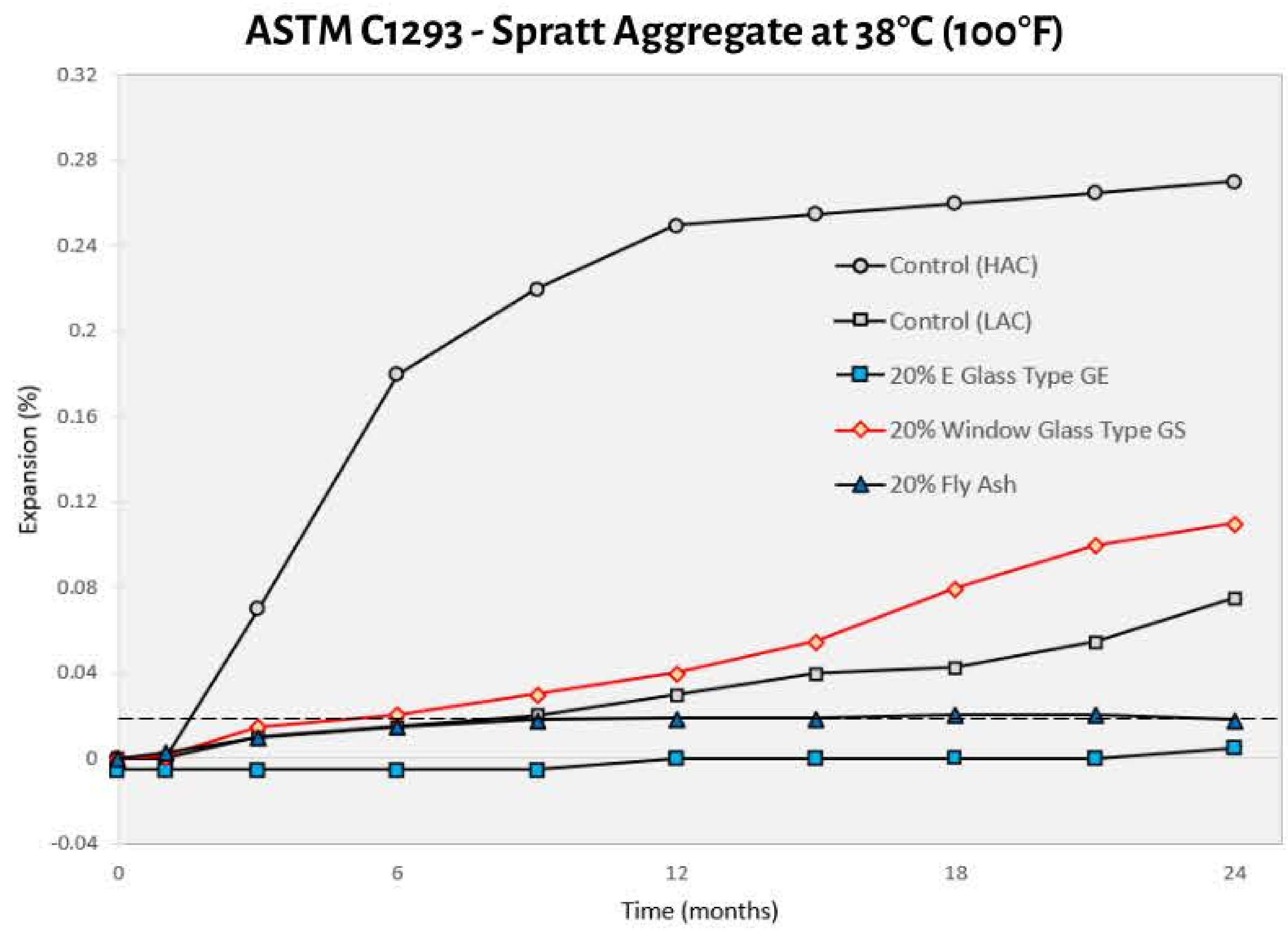
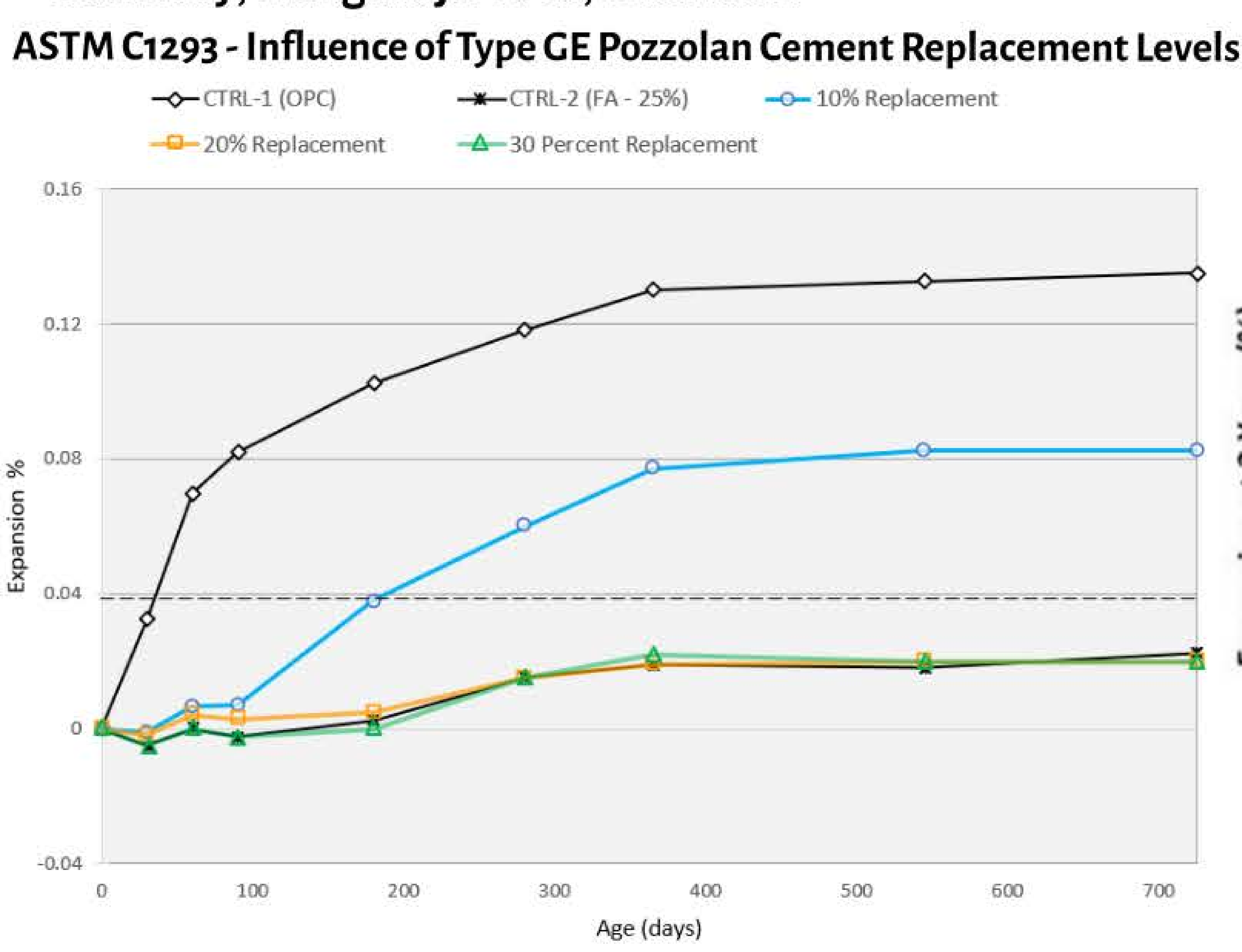


Figure 7

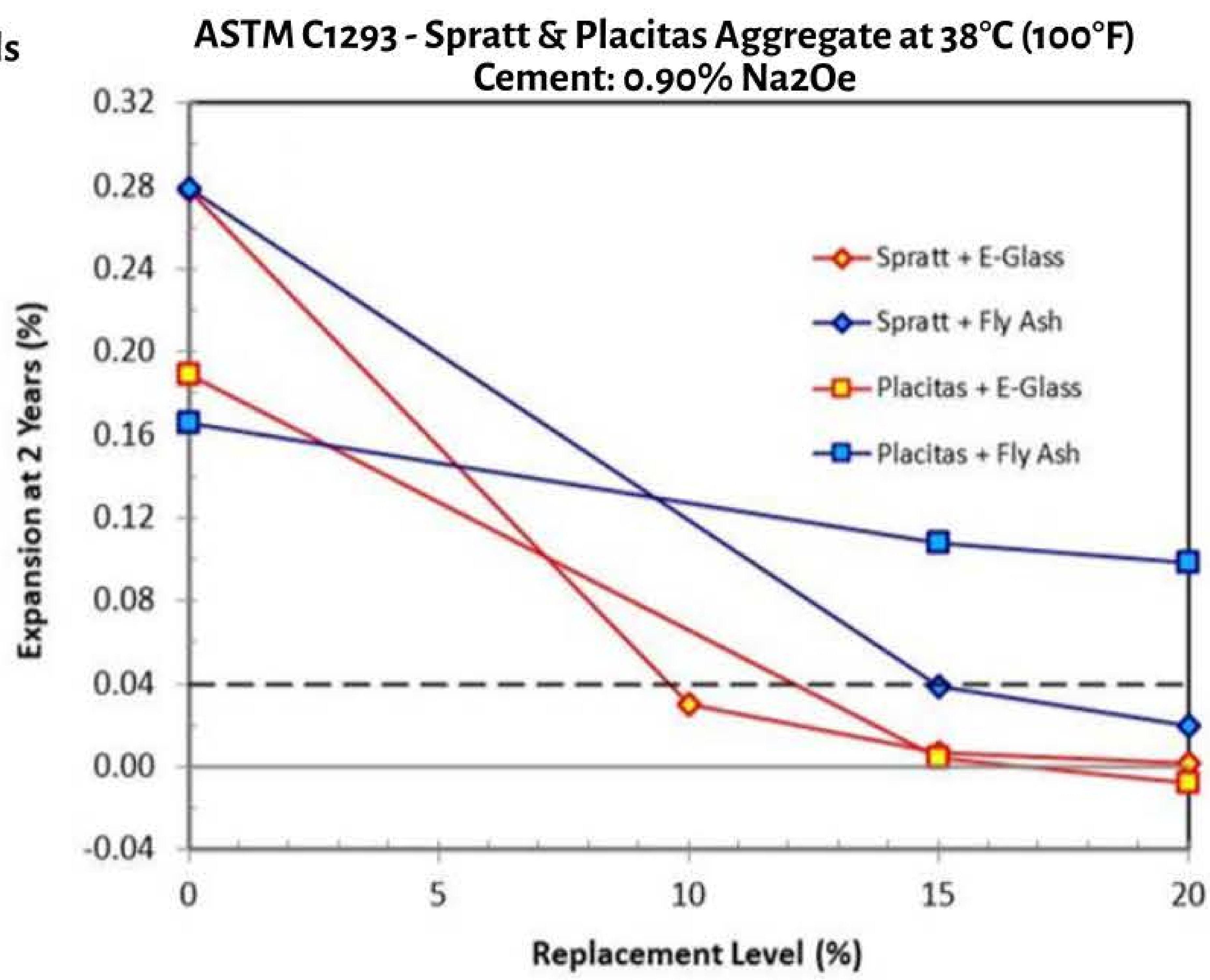
Influence of Type GE Pozzolans Dosage on Concrete Prism Expansion Containing Reactive Las Placitas Gravel Aggregate in CPT (ASTM C1293). Courtesy, Rangaraju et al, Clemson.



[Type GE Pozzolan Properties: LOI – 1%; Avg. Dia. 4 microns; Sp. G = 2.60; Blaine Fineness = 10,200 cm2/g]

Figure 8

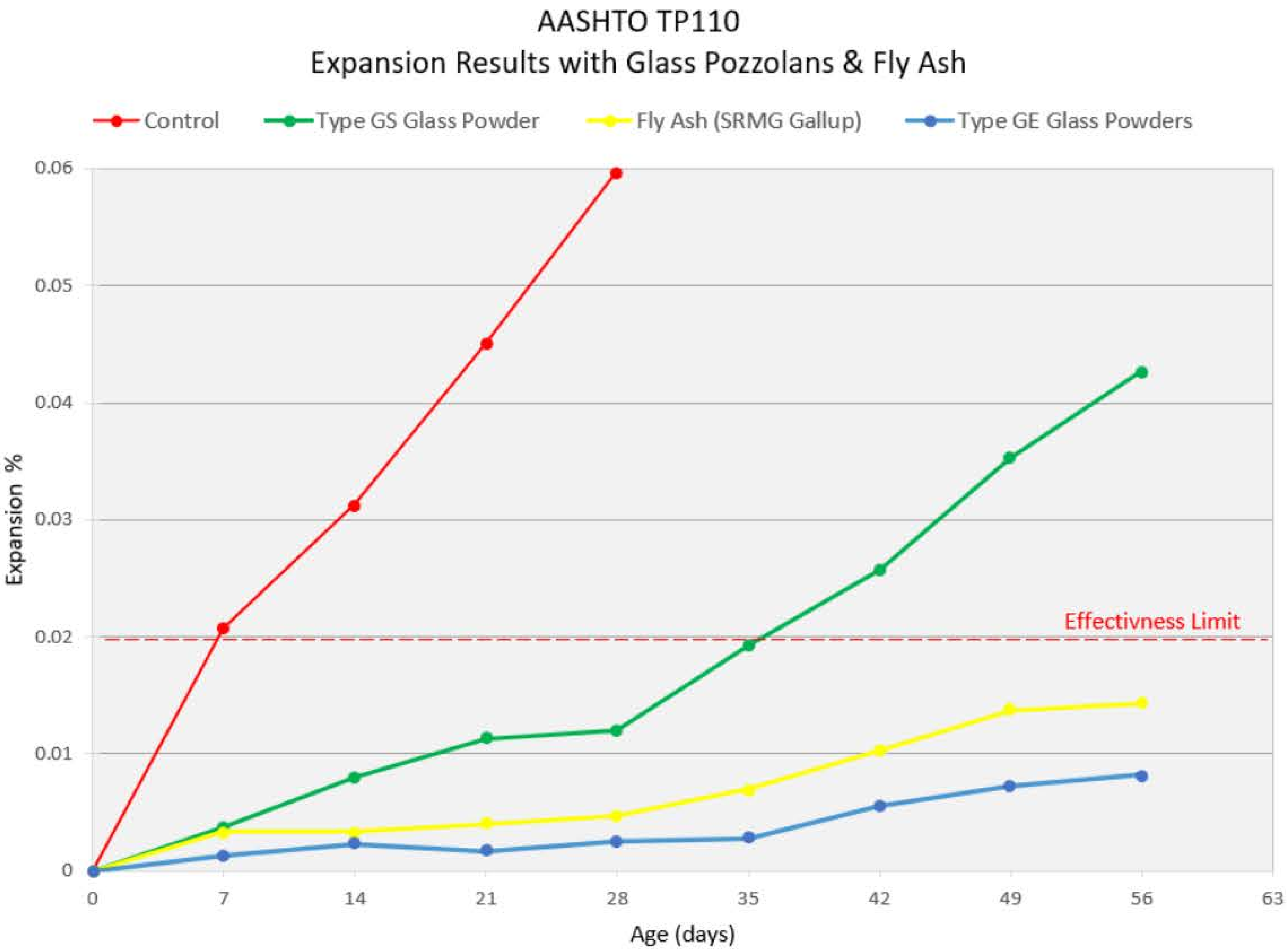
ASR mitigation data on cement replacement levels needed for Spratt and New Mexico aggregates. Courtesy Mike Thomas.



Depending on the reactive aggregate, various cement replacement levels of Type GE glass pozzolans are required. In all cases, Type GE pozzolans can mitigate ASR at lower replacement ratios than Fly Ash.

Figure 9

Comparison of ASR mitigation using AASHTO TP110 Concrete Prism test with New Mexico aggregates. Type GE pozzolans and fly ash both successfully mitigate ASR at 25% cement replacement, whereas Type GS glass pozzolans do not adequately mitigate ASR. Courtesy AMEC Foster Wheeler/Hemmings.



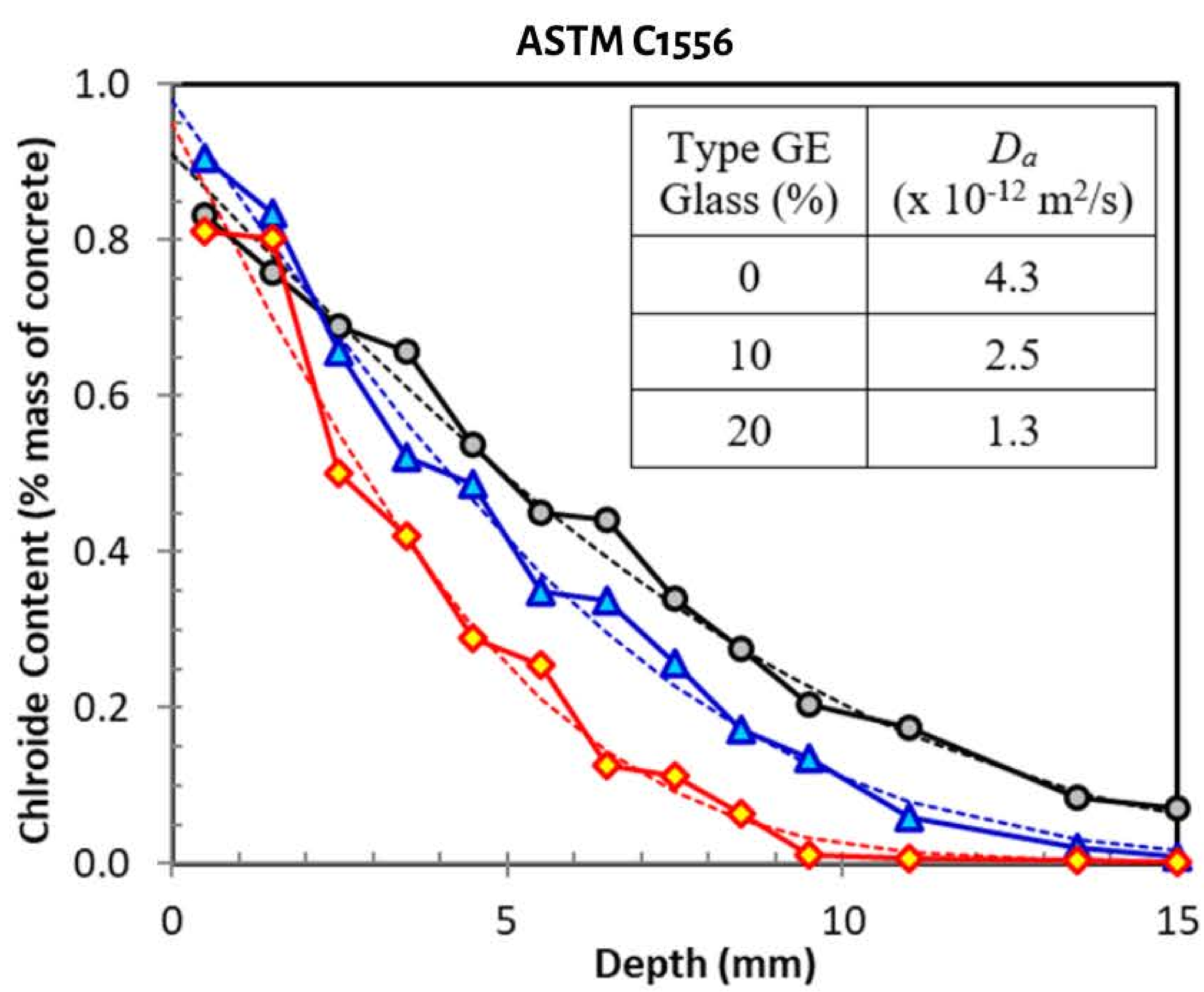
The ASTM C1293 test takes two years to render a result, so we have found that AASHTO TP110, which is a concrete prism test, takes 60 days and is a good proxy. Also, ASTM C441 has always been an excellent screening test for the efficacy of pozzolans to prevent expansion in reactive borosilicate glass (Pyrex).

Figure 10

Rapid Chloride Permeability (ASTM C1202)

Age (Days)	Control	Coulombs 80:20 VCAS
28	>6000	1600
56	9300	920
150	7500	400

Charge Passed	Chloride Ion Penetrability
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very Low
<100	Negligible

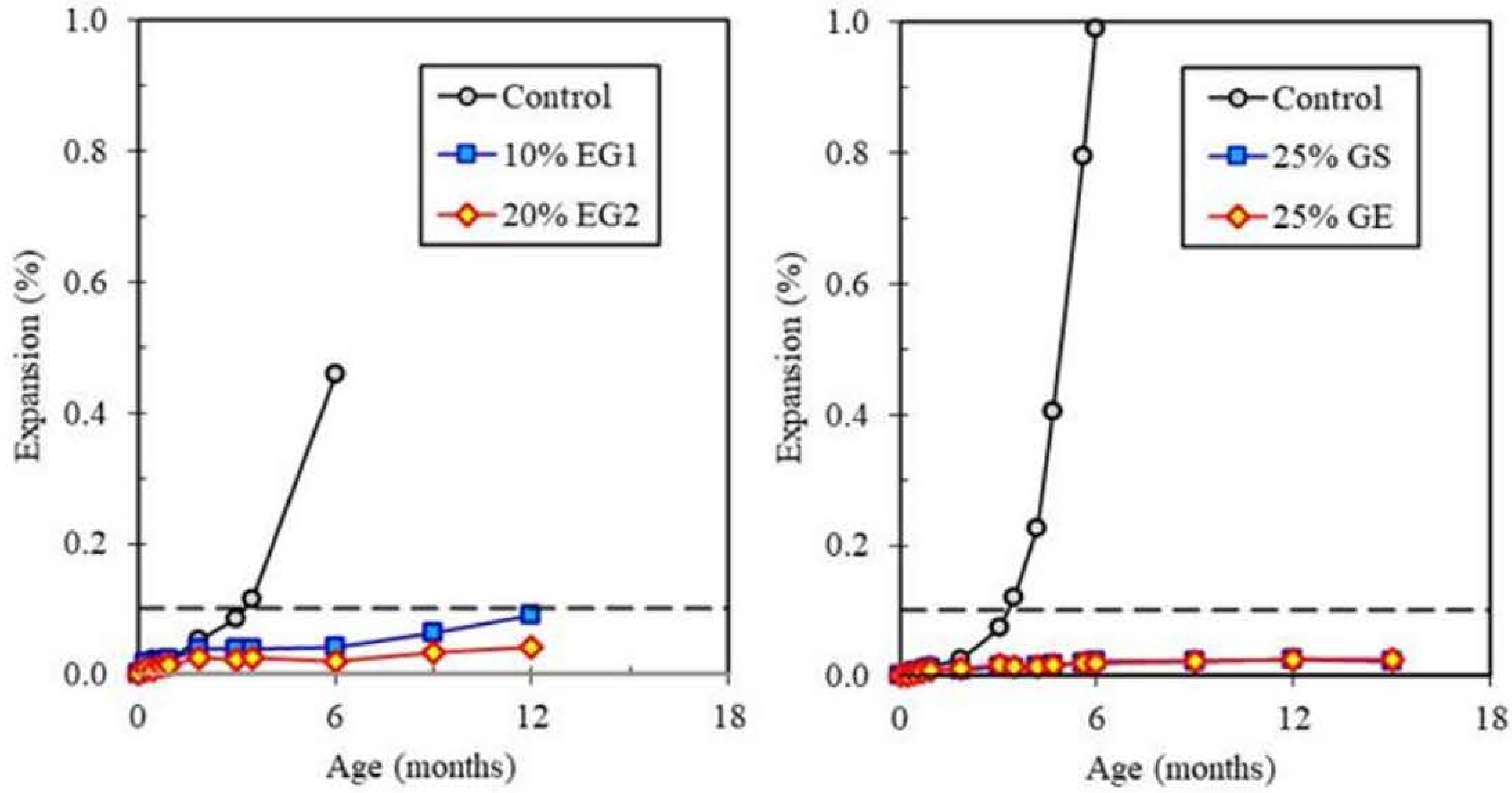


Glass pozzolans are quite effective at significantly reducing chloride ion permeability. The left graph shows ASTM C1202 at 20% cement replacement. The graph on the right indicates that Type GE pozzolans, when tested with ASTM C1556, the Chloride Diffusion test, are extremely effective at cement replacements of 10%, and that 20% replacement almost completely stops chloride diffusion at depth. As a practical matter, time to corrosion of embedded steel rebar is increased 2-3 times by the use of Type GE Glass. Courtesy Thomas and Hemmings.

Figure 11

Improved Sulfate Resistance

Evaluation of sulfate resistance testing for Type GS and Type GE Glass Pozzolans per ASTM C1012. Courtesy Mike Thomas.



The results from testing (ASTM C1012) to evaluate sulfate resistance are shown in Figures 11 for two separate studies.

The first of these studies, on the left, was concerned with the use of ground E-glass, and data are shown for replacement levels of 10% and 20%. Both levels of replacement were successful in reducing the expansion of a high-C3A Portland cement (control mix expansion 0.459% at 6 months) to below the limits for Type HS cement (0.05% at 6 months and 0.10% at 1 year), when blended with a high-C3A Portland cement.

The second study, on the right, was part of a wider study on the use of pozzolans in concrete (Kasaniya, 2019) and the data show the expansion of mortar bars with either 25% ground GS or GE glass, both of which were capable of reducing expansion to acceptable levels (meeting limits for Type HS cement) when blended with a high-C3A cement (control mix expansion 0.99% at 6 months)."

Summary

Both Type GS and GE glass powders are excellent reactive pozzolans contributing to reducing the carbon footprint of concrete structures. Type GS pozzolans can be used indoors and where reactive aggregates are not a consideration. Type GE pozzolans are more effective than fly ash in mitigating ASR with the further advantage of being as white as white cement. Type GE pozzolans are also excellent in preserving colorfastness in pigmented concrete precast, GFRC, and flooring. Nanosilica HR 50 works well in situations where a white, highly reactive replacement for silica fume is required.

Appendix

ASTM C109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

ASTM C311/C311M Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete

ASTM C441 Standard Test Method for Effectiveness of Pozzolans or Ground Blast Furnace Slag in Preventing Excessive Expansion of Concrete due to Alkali-Silica Reaction.

ASTM C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

ASTM C1012 Standard Test Method for Length Change of Hydraulic Cement Mortars Exposed to a Sulfate Solution

ASTM C1069 Test Method for Specific Surface Area of Alumina or Quartz by Nitrogen Adsorption

ASTM C1202 Standard Test Method for Electric Indication of Concrete's Ability to Resist Chloride Penetration

ASTM C1240 Standard Specification for Silica Fume Used in Cementitious Mixtures

ASTM C1293 Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction

ASTM C1556 Standard Test Method for Determining the Apparent Chloride Diffusion of Cementitious Mixtures by Bulk Diffusion.

ASTM C1567 Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)

ASTM C1778 Guide for Reducing the Risk of Deleterious Alkali- Aggregate Reaction in Concrete

AASHTO TP110 Standard Method of Test for Potential Alkali Reactivity of Aggregates and Effectiveness of ASR Mitigation Measures (Miniature Concrete Prism Test MCPT)