ALKALI-SILICA REACTIVITY
RESEARCH SUMMARY
STALITE LIGHTWEIGHT AGGERGATE

BACKGROUND

Alkali-Silica Reactivity, also termed ASR, is the expansive deterioration of concrete due to a chemical reaction involving components in aggregates and the cement paste. At the natural pH of concrete (approximately 12.4) and in the presence of calcium hydroxide and water (compounds normally present in concrete), many siliceous minerals in aggregates eventually will decompose into silica gel. This may take anywhere from a relatively short to an extremely long time.[1] The formation of the silica gel produces expansive pressures which exceed the tensile strength of the concrete resulting in cracking.

ASR MORTAR BAR TESTS

1994 LAW ENGINEERING TESTS[2]

Carolina Stalite provided an approximately 100 pound sample of Stalite ¾-inch, rotary kiln expanded slate aggregate. The Stalite aggregate was crushed in the laboratory, separated into size fractions and recombined to meet the gradation requirements of ASTM C227. The mixtures used were specified by ASTM C227. The aggregate batch weights presented in ASTM C227 were adjusted to compensate for the difference in specific gravity between the Stalite aggregate and the natural aggregate being tested. The procedure was followed so that both the Stalite and the reference mixtures had the same aggregate and paste volumes. The water-cement ratio of the Stalite mixture was 0.51 to produce a flow of 118.

Law Engineering obtained natural quartzite sand from Waugh, Alabama for use in the reference mixture. The natural sand is widely used in the concrete construction in the Atlanta area and has an acceptable performance history with respect to alkali reactivity in local projects. The natural sand was separated into size fractions and recombined in accordance with ASTM C227. The mortar bar mixture was proportioned in accordance with ASTM C227. The water-cement ratio of the reference mixture was 0.50 to produce a flow of 111.

Law Engineering obtained a sample of Type 1 portland cement from Birmingham, Alabama for use on the project. The cement was tested to verify its alkali content. The total alkalis, reported as Na_2O was measured to be 0.75 percent when tested in accordance with ASTM C 114-88 "Standard Test Methods for Chemical Analysis of Hydraulic Cement".

Stalite Aggregate Mixture					
Reading Age	Length Change %				Average Length Change %
	A	B	C	D	
1 Day	0.000	0.000	0.000	0.000	0.000
14 Days	0.007	0.007	0.007	0.007	0.007
28 Days	0.007	0.007	0.007	0.007	0.007
2 Months	0.012	0.011	0.011	0.011	0.011
3 Months	0.015	0.014	0.014	0.013	0.014
4 Months	0.018	0.018	0.018	0.016	0.018
6 Months	0.018	0.017	0.018	0.016	0.017
9 Months	0.016	0.015	0.016	0.014	0.015
12 Months	0.017	0.016	0.017	0.016	0.017

Reference Mixture					
Reading Age	Length Change %				Average Length Change %
	A	B	C	D	
1 Day	0.000	0.000	0.000	0.000	0.000
14 Days	0.008	0.005	0.005	0.005	0.006
28 Days	0.008	0.004	0.004	0.004	0.005
2 Months	0.012	0.008	0.007	0.008	0.009
3 Months	0.013	0.010	0.009	0.009	0.010
4 Months	0.015	0.012	0.012	0.012	0.013
6 Months	0.017	0.014	0.013	0.013	0.014
9 Months	0.013	0.010	0.010	0.011	0.011
12 Months	0.013	0.012	0.010	0.012	0.012

2003 FROEHLING AND ROBERTSON RESULTS[3]

In January of 2003, Carolina Stalite supplied a 100-pound sample of ¾-inch, rotary kiln expanded slate aggregate to FROEHLING AND ROBERTSON in Richmond, Virginia. The aggregate was tested in combination with high alkali cement in general accordance with ASTM C227-97a. The results of the testing showed the aggregate to be non-reactive based on Appendix X1.3.2 of ASTM C33.

Test Age	Average Length Change, %
14 days	0.001
1 Month	0.005
2 Months	0.007
3 Months	0.010
4 Months	0.011
5 Months	0.012
6 Months	0.013

PETROGRAPHIC ANALYSIS

2000 AND 2003
Petrographic Examination of Stalite Lightweight Aggregate[4]

Petrographic analysis involves the optical examination of concrete specimens under low and high power magnification. Detailed instructions on conducting a petrographic examination of hardened concrete can be found in ASTM C856, "Standard Practice for Petrographic Examination of Hardened Concrete". For our examination, a sample of the aggregate was impregnated with blue dye under vacuum. The impregnation under vacuum causes the dye to permeate every crack, micro crack and all pores, including micro pores in the aggregate sample. The impregnated aggregate is cut and placed on a glass plate, ground and polished to a thickness of about 30 microns.

The thin section of aggregate was examined for the following features:

- Forms of silica in aggregate
- The void system in aggregate
- Presence of cracks and micro cracks

The sample was examined using a magnification of 40X.

Findings from Petrographic Analysis

In 2000 Dr. Coleman found that the form of silica does not pose a threat of potential alkali silica reaction product when used in concrete, namely, no microcrystalline forms of silica were found in silica grains well distributed in the aggregate. The aggregates were fairly uniform and no significant varieties were identified. The lightweight aggregate examined is thus suitable for use in concrete.

In the 2003 study, three aggregates were randomly picked and evaluated. The aggregates ranged in texture from fairly dense to porous aggregates as shown in Figures 1 & 2. Figure 1 shows a dense lightweight aggregate with some voids

(blue spots); and Figure 2 shows a porous aggregate with a wide range of air void sizes, as indicated by the blue areas.
Dr. Coleman found the form of silica in the aggregates did not appear to be of the form that will pose a danger to its use in concrete; namely, be susceptible to alkali-silica reaction when used with a high alkali cement.
No cracks or micro-cracks were found in any of the randomly picked samples that were examined.

CYLINDER ANALYSIS

In 1994 Law Engineering[2] made several 3-inch diameter by 6-inch concrete cylinders using the same volumetric proportions as the ASTM C 227 mortar bars. Approximately 50 percent of the aggregate in the cylinders was uncrushed, ¾-inch maximum sized, lightweight aggregate particles. The uncrushed lightweight aggregate particles were included in the cylinders to represent the aggregate in a typical lightweight structural concrete mixture. The cylinders were cured in the same conditions as ASTM C227 specifications.

Fractured faces of the cylinders were observed using ultra-violet light technique presented in SHRP-C/FR-91-101, Handbook for the Identification of Alkali-Silica Reactivity in Highway Structures".

The Stalite aggregate particles in the cylinder specimens did not exhibit visible indications of alkali-silica reactivity when viewed using the ultraviolet light technique and a 10X magnification at one year.

CONCLUSIONS

All the test results indicate that Stalite expanded slate lightweight aggregate is suitable for use with high alkali cements. Furthermore ACI 201.1.R reports no documented instance of in-service distress caused by alkali reactions with lightweight aggregate. No evidence of alkali silica reaction was observed in tests conducted on 70-year old marine structures and several 30 plus year old bridge made with lightweight aggregate concrete.

Though laboratory studies and field experience have indicated no deleterious expansion resulting from the reaction between cement and silica in the lightweight component of the aggregates, the natural aggregate portion of a sand-lightweight concrete mixture should be evaluated in accordance with applicable ASTM standards. [5]

References:

[1]Stokowski, Jr., Steven J., & Sarson, Janet, Stone Products Consultants, 10 Clark Street, Suite A, Ashland, Massachusetts, 01721, United States of America
[2] Viness, Terry and Love, John, Lightweight Aggregate Alkali Silica Reactivity Testing, Law Engineering and Environmental Services Atlanta, Georgia 1995
[4] Coleman, S. Ebow, Petrographic Examination of Stalite Lightweight Aggregate, C3S-Houston Texas 2000 and 2003
[5] Crenshaw, James and Hill Robert, Potential Alkali Reactivity Report, Froehling and Robertson Richmond, Virginia 2003
[5] ACI 213-R 03 Guide for Structural Lightweight Aggregate Concrete

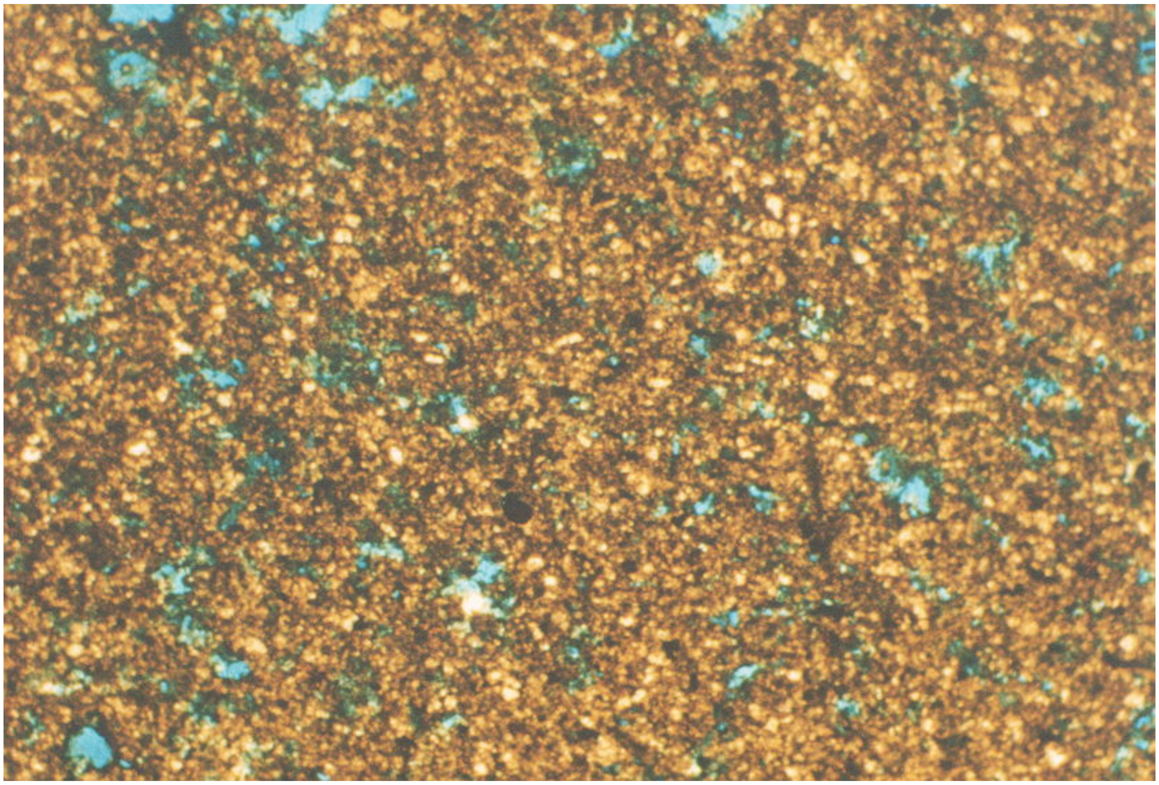
Figure 1 shows relatively dense lightweight aggregate with tiny voids

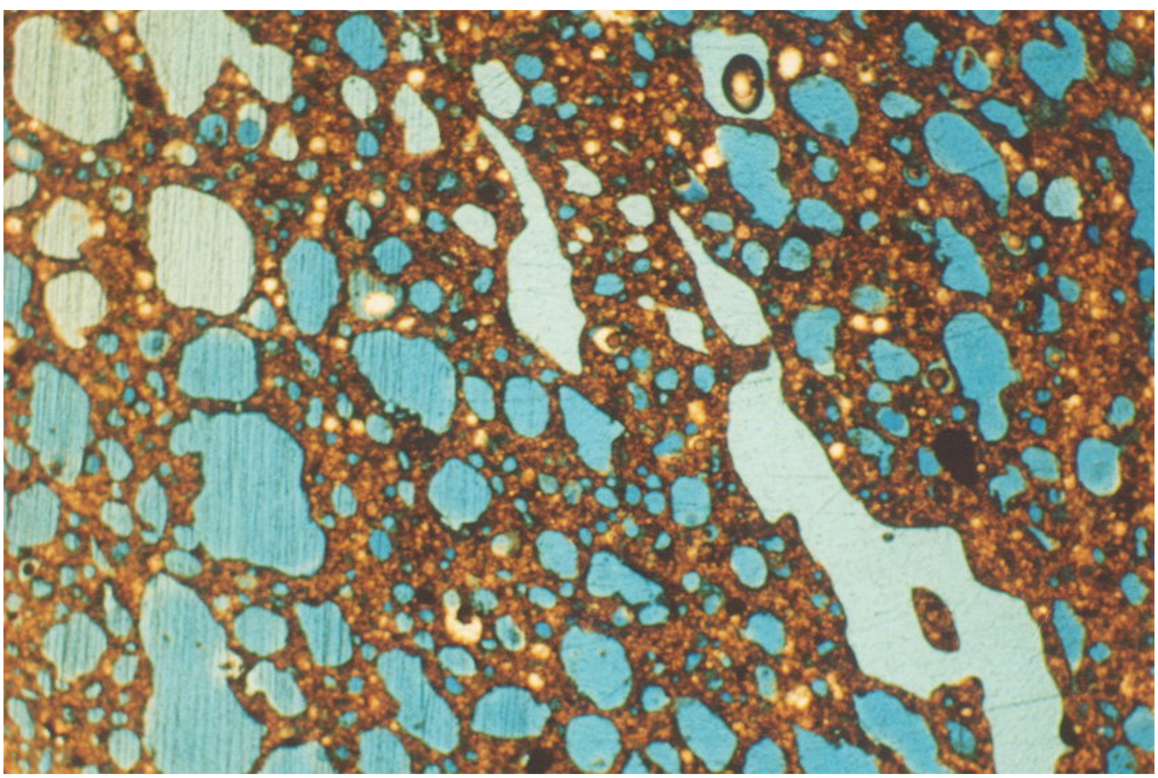
Figure 2 shows a wide range of air voids in lightweight aggregate