

Alkali-Aggregate Reactivity — A Summary*

by PCI Committee on Durability

Comments by Bryant Mather and Committee

BRYANT MATHER†

The Durability Committee's report on alkali-aggregate reactivity is, in general, a fair summary of the subject. However, there are a number of points that I would like to address.

1. On p. 28 in the third paragraph, change "Three" to "Two," change "have been identified" to "are recognized" and delete "alkali-silicate." It is true that, from time to time, someone believes he has found a new class; there was "cement-aggregate reaction," then there was "alkali-silicate." It is now agreed that there are only two classes.

2. On p. 29, Section 2.0, first paragraph, delete "and natural aggregates containing more than 95 percent silica." In the first place, opal, chalcedony, chert, and strained quartz are all natural aggregates that are close to 100 percent silica — so the phrase above suggesting this is something different is wrong. Second, unstrained quartz, the principal constituent of most aggregates that are over 95 percent silica, is not reactive. Also, in the line before, delete "other," because the items preceding are not volcanic rocks.

Later in this section, in the paragraph beginning "Alkalies (Na_2O and K_2O)..." it would be more accurate to say "Alkali ions in the pore fluid of concrete are usually initially associated with sulfate or chloride ions since they are derived from water-soluble alkali salts such as potassium sulfate or sodium chloride. In concrete, the sulfate or chloride ions react with the aluminate in the cement, leaving the alkali ions to associate with hydroxyl ions and, thus, raise the pH of the fluid. It is the high pH of the pore fluid that

makes it react with and convert the unstable forms of silica to an alkali silica gel which is expansive when it takes up water." [I would not say this but, if one thinks about it, what has just been said is use of a zero C_3A cement might prevent an alkali-silica reaction (ASR).]

In the last paragraph on p. 29, third line, replace "minerals" with "materials;" opal is a mineraloid, rhyolite is a rock. In other words, not all reactive materials are minerals.

3. On p. 30, is the rimmed particle in Fig. 3.1 really ASR? It looks very much like rimmed alkali-carbonate rock reaction examples. It could, however, be ASR.

I would urge deletion of the 15 lines pertaining to delayed ettringite formation as it is a complete red herring, scientifically, vis-à-vis ASR.

In the last line of the second paragraph, delete "electron spectroscopic" — this is a meaningless pair of words.

In Section 3.2, replace "less than 0.6 percent total alkali expressed as Na_2O " with "(less than 0.60 percent alkali expressed as Na_2O equivalent, i.e., percent Na_2O + 0.658 x percent K_2O)." Without quibbling, 0.60 is quite different from 0.6.

In Section 3.3, replace "measure the level of reactivity of the aggregate with a known high alkali cement" with "detect whether or not material from a given source is potentially deleteriously reactive." (Petrographic examination, the next item, does not "measure reactivity" with a high-alkali cement.)

4. In Fig. 4.1, p. 31, for "Cement Alkalinity of 0.5% (Equivalent Na_2O)" read "Alkali Content of Cement, $\text{Na}_2\text{O}_{\text{eq}} = 0.50\%$." (Alkalinity is measured on the pH scale.)

In Section 3.3, third paragraph, replace "Proposal P214

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† Director, Structures Laboratory, United States Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

'Proposed'" with "C 1260." C 1260 replaced P214 in March 1994.

In Section 3.4, the phrase "pozzolanic materials such as ground granulated blast-furnace slag" is simply incorrect. "Pozzolan" is defined as a material that is not a hydraulic cement; ground granulated blast-furnace slag is a hydraulic cement. The sentence should read "The use of cementitious materials such as ground granulated blast-furnace slag or pozzolans such as fly ash and silica, together with portland cement, have proven..."

In Section 4.1, third line from the end, for "and a known alkalinity in the cement" read "used with cement of 0.50 percent Na₂O equivalent."

Also in Section 4.1, Ref. 19 referring to "Eliminating or Minimizing Alkali-Silica Reactivity" should be replaced with:

19. Stark, David, Morgan, Bruce, Okamoto, Paul, and Diamond, Sidney, "Eliminating or Minimizing Alkali-Silica Reactivity," SHRP Report C-343, Strategic Highway Research Program, National Research Council, Washington, D.C., 1993, 266 pp. (p. -)

The page number from which Fig. 4.1 comes should be given in the reference. I cannot find it in the report. I do not find that the project involved the study of curing tempera-

ture as a variable. My view is that the results are possible, but, unless referenced to a procedure, they are meaningless. Generally, elevating the curing temperature increases early expansion but ultimate expansion of the ones cured at a lower temperature is usually greater.

On p. 32 in Section 4.4, why keep dragging in "delayed ettringite formation"? It really does not exist as an established phenomenon. The last two paragraphs of Section 4.4 would best be deleted.

5. In Section 5.0, it would be better if mention had been made of the cases where, because sealers seal, the ASR problem got much worse. It is noted that dry concrete is less likely to get into trouble. A slab-on-grade could be dry enough often to be less active but a sealed slab-on-grade will be at 100 percent internal relative humidity all the time.

6. On pg. 33, Ref. 11 should read:

11. "Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)," ASTM C 1260-94, American Society for Testing and Materials, Philadelphia, PA.

Lastly, I would suggest deleting Refs. 5 and 22 as irrelevant to ASR.

COMMITTEE CLOSURE§

Mr. Mather's comments are insightful and detailed and we thank him for his interest in the report on alkali-aggregate reactivity.

The intent of this document was to provide a summary, in layman's terms, of a relatively complex subject. Some of the submitted comments, while technically accurate, move away from this intent to simplify. The document is not and was not intended to be a state-of-the-art dissertation. As a result, there are areas in the report where data are lacking, such as reference to cases where sealers may aggravate alkali-silica reaction (ASR). As a committee, we attempted to include as many real life examples as possible. If we were not able to substantiate anecdotal information, we did not include the material.

The following is the committee's response to Mr. Mather's specific comments on a point by point basis:

1. The report indicates there are three classes of alkali-aggregate reactions. While some may agree there are only two classes, at least one source lists three. The main focus of the summary is ASR.

2. Mr. Mather's point about deleting "other" is well taken. The committee believes the statement about 95 percent silica is accurate. An additional statement regarding the effect of the microcrystalline phase on reactivity would be beneficial.

Mr. Mather's comments on alkali ions in the pore fluid provide additional detail to a section that we believe is simply and accurately described. The committee tried to keep in mind that most of the readers are not graduate chemists.

The distinction between minerals and materials, while technically correct, is probably beyond the average reader.

3. Fig. 3.1 was not specifically identified as ASR but discussed under the section titled "Alkali-Aggregate Reaction." The rimmed particle does resemble alkali-carbonate reaction; however, the petrographer at W.R. Grace & Company believes that this particle is a graywacke containing silicate and not carbonate minerals. The concrete core sample also contains reacted and distressed particles of sandstone or quartzite. Fractures within the aggregate extend into the surrounding paste and were partially filled with silica gel, a product of ASR.

The reference to delayed ettringite formation was included by committee consensus as a result of the large body of evidence regarding the simultaneous occurrence with ASR in several case histories. Ramboll & Hanneman Bulletins No. 40 "Simultaneous Presence of Alkali-Silica Gel and Ettringite in Concrete" and No. 47 "Heat Cured Induced Expansion," in addition to the referenced articles in the committee report, deal with this subject. The committee felt it was important to bring this issue to the reader based on the number of instances where failures record evidence of both phenomena occurring in heat cured elements. We believe that evidence shows that delayed ettringite formation is an established phenomenon.

Mr. Mather is quite correct in pointing out that "electron spectroscopic" is meaningless. The text should read "optical and electron microscopic techniques."

In Section 3.2, once again, the reference to 0.60 percent may be technically correct; The committee believes the intent is clear to the average reader.

Section 3.3 is another example of text that is understand-

§ This response is based on a collaboration between Kenneth B. Rear of W.R. Grace & Co. and Donald F. Meinheit of Wiss, Janney, Elstner Associates with input from the petrography department of W.R. Grace.

able and useful to the reader vs. text that is technically and grammatically correct.

4. I agree that cement alkalinity is not correct. This inconsistency should have been picked up in the review process.

ASTM C1260 is correct. At the time this summary was written and reviewed, Proposal P214 was correct. The terminology did not get changed in the publishing process.

Lea states in *The Chemistry of Cements and Concrete* that "granulated slag alone has similarly a negligible cementing action, but, if some suitable activator is present, all except the more silicious granulated slags show marked cementitious properties." This appears to satisfy our understanding of the definition of a pozzolanic material. Having said all that, a more appropriate term for all the referenced "pozzolans" would be "supplemental cementing materials" as used in the Canadian Standard CAN/CSA-A23.5. Lea states that the product of grinding Granulated Ground Blast-Furnace (GGBF) slag with portland cement clinker forms the British and U.S. portland blast furnace cements and mixing GGBF slag with hydrated lime forms American slag cement. There appears to be a controversy in the industry over

the terminology of slag vs. slag cement. We have chosen to use Lea's definition.

For Section 4.1, we prefer Mr. Mather's text in reference to the issue of alkali and cement.

Concerning the SHRP Report C-343 (Ref. 19), this graph came directly from David Stark. We are at a loss to explain why the graph was not included in the report. Our intent here was simply to raise the reader's awareness of the potential problems that have occurred with heat treated concrete sections.

Concerning delayed ettringite, see the comments above.

5. Regarding sealers — Mr. Mather's comments are valid. However, we were limited to describing cases that were submitted to the committee. We found, to our surprise, that there were a number of anecdotal examples but few documented cases submitted on North American ASR problems.

6. Concerning Ref. 11, see the comments in No. 4 above.

Lastly, the committee would like to thank Mr. Mather for his thoughtful review of the document. As always, we find that his comments stimulate thought and ideas, and generally result in an improved report.

DISCUSSION NOTE

The Editors welcome discussion of reports and papers published in the PCI JOURNAL. The comments must be confined to the scope of the article being discussed. Please note that discussion of papers appearing in this issue must be received at PCI Headquarters by September 1, 1995.