NOTES ON CEMENT-AGGREGATE REACTION IN CONCRETE

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During the past few years, engineers, including some who are among the leaders in design and construction of concrete structures, have become convinced that the rocks and minerals used as concrete aggregates are not chemically inert as had been more or less tacitly assumed during earlier decades. The concept of cement-aggregate reaction has been considered with increasing interest wherever engineers associate, and numerous publications on the subject have made their appearance in the engineering literature.

In this brief note, it is not intended to discuss the fundamental principles involved in the interaction between cement and aggregate, although some reasonable theories have already been proposed; it is the intention of these comments merely to call to the attention of mineralogists and petrographers an important engineering application of their science.

During the summer of 1941, the Bureau of Reclamation, having become adequately convinced of the deleterious nature of interactions between some aggregates and cements containing more than 0.6 per cent of alkalies (soda plus the sodic equivalent of potassa), greatly extended the facilities and staff of its Petrographic Laboratory. One of the foremost duties of the laboratory staff was an investigation of the causes, effects, and preventative measures of cement-aggregate reaction. The results of some of these investigations will appear in the near future.

Experience has proved that several types of natural aggregate materials are capable of interaction with the alkaline solutions which persist in cement paste subsequent to set of the concrete when high alkali cements are employed in the mix. Most reactive are opal-bearing rocks of all sorts, but certain glassy volcanic rocks of acid to intermediate compositions and certain chalcedonic rocks (including some cherts) behave in a similar manner although possibly to a lesser degree. In addition to the forenamed rocks containing glasses or hydrated silica, some phyllites and/or low grade schists also furnish conclusive evidence of reactivity. In this instance the reactivity may be associated with the occurrence of large quantities of hydromicas in the phyllites; however, rocks of this sort are known to have caused difficulty in only a few cases and for this reason a more thorough investigation of the reactivity of phyllites has not been undertaken to date.

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Evidences of cement-aggregate reaction become manifest through several phenomena: unsightly cracking on the surfaces of concrete structures, exudation of gelatinous deposits, etc. The most alarming effects from the engineering standpoint, however, are the expansion and deterioration in strength of the concrete. In some instances, these effects may become so serious as to necessitate extensive repairs or replacements.

TABLE 1. EXPANSIONS OF LABORATORY MORTAR BARS FABRICATED WITH HIGH ALKALI CEMENT
(Various Reactive Aggregates Substituted for Quartz)*

Substituted material			Expansions in per cent	
	Size	Per Cent	6 months	12 months
Vein quartz, Colorado	G	—	.025	.033
Rhyolites and Andesites, Parker Dam	8	19	.280	.398
Andesites, Friant Dam	G	100	.262	.371
Acid Volcanics, Kimball, Nebraska	G	100	.519	.665
Cherts, Kimball, Nebraska	G	100	.757	.863
Novaculite, Arkansas	G	75	.499	.537
Obsidian, Lake Co., Oregon	G	75	.065	.261
Pitchstone, Colorado	G	50	.561	.699
Opaline shale, California	30	4¾	.867	1.655
Opal, Nevada	G	5	1.723	2.218
Phyllite, Virginia	8	19	.095	.201
"Pyrex" (glass)	G	50	.841	.874
Alunite, Utah	G	5†	.832†	1.351†

* All bars contained 1 part cement to 2 parts aggregate (by weight); aggregate was graded according to sizes; bars were cured in a moist atmosphere at 100° F.; cement No. 2742 (Na_2O 1.30, K_2O 0.12). Combinations indicated by "G" in the second column contained 20 per cent of each size from No. 8 to No. 100 sieve and substitutions were made for all sizes; otherwise the test material was substituted for equal quantities of quartz for the size shown.

† Expansions are shown only for 5 per cent substitution because bars containing large amounts of alunite expanded beyond the range of the comparator at early ages.

(All data obtained in the laboratories of the Bureau of Reclamation, U. S. Department of the Interior, Denver, Colorado.)

Although the field service history of concrete is the ultimate basis for judging its quality, laboratory test bars frequently provide valuable information on expansive potentialities. One of the early phases of the Bureau's program of investigation consisted of preparing mortar bars with numerous common minerals likely to occur in many natural aggregates. These minerals included quartz, feldspars of several compositions, the commoner accessory minerals of igneous rocks, etc. Without exception the primary minerals of phaneritic igneous rocks showed insignificant expansions when used with high alkali cement in the fabrication of mortar bars. Comparative data on the expansions of several of the more reactive aggregates are shown in Table 1.

Typical reactive aggregates contain silica and/or silicate minerals and show significant expansions only when high alkali cement is used. An interesting example of a mineral that reacts with both low and high alkali cement is alunite, the behavior of which might have been predicted from its composition and the presumption of its attack by cement solutions. Sulfate-bearing solutions have long been known to cause destructive attack on concrete, and thus it is not particularly surprising that this mineral should produce extreme expansion (Table 1) and distortion of laboratory bars. Fortunately however, alunite is not known to occur in significant quantities in any natural aggregate.

Volcanic rocks are particularly abundant in the western portions of the United States and have furnished numerous examples of reactivity as aggregates. However, the occurrence of reactive cherts, opal-bearing rocks, and reactive phyllites in other regions of the country cannot be safely ignored. These several examples serve to emphasize the importance of the mineralogical and petrographic study of concrete aggregates.