

AAR INVESTIGATION OF CONCRETES FOR STORAGE OF RADIOACTIVE WASTE

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ABSTRACT

Alkali-aggregate reactivity in concretes for waste disposal facilities could be a major source of concrete deterioration and thus shorten the service life of the facility, if the reactivity is above a certain level. Therefore, a careful evaluation of alkali-aggregate reactivity is important to ensure the required long-term durability of such concrete. The current studies employed both short-term accelerated and long-term standard test methods, and compared results with those of reference reactive and non-reactive aggregates. Accelerated tests were also run for cores from field concrete samples. The experimental methods employed are described and the results presented and evaluated to describe some marginally reactive aggregates.

Keywords: Alkali-aggregate reactivity, carbonate rocks, radioactive waste disposal.

INTRODUCTION

Alkali-Silica Reaction. Alkali-carbonate reaction (ACR) and (ASR) alkali-silica reaction are the two typical types of alkali-aggregate reaction that have been known to occur in concrete, in addition to a lesser known slow/late-expanding alkali-silica/silicate reaction (Rogers 1990a, 1990b). The alkalis participating in the alkali-aggregate reactions are mostly derived from the cement itself and, if used, mineral admixtures such as fly ash, slag, silica fume, etc. ASR in concrete is associated with the reactions of reactive silica components in aggregates with alkali (Na^+ and K^+) and hydroxyl (OH^-) ions in the pore solution, formed mostly from the dissolution of alkali compounds of anhydrous cement clinker in the mix water. The reactive silica components commonly found in concrete aggregates are those of opal, tridymite, cristobalite, volcanic glasses, chalcedony, cryptocrystalline to macrocrystalline and macrogranular quartz with deformed crystal lattice or rich in secondary inclusions, and fine to coarse microcrystalline quartz (Dolar-Mantuani 1983, pp. 84-113). The presence of interconnected pores in the siliceous aggregates and possibly the presence of a partial deposit of amorphous silica in these pores are known to promote alkali-silica reactivity (Diamond, 1976).

In concrete, reactive silica components of aggregate are attacked by the hydroxyl ions in the pore solution. In the process, hydroxyl ions diffuse into the accessible surfaces of reactive silica particles and react with surface silica groups. The hydroxyl ion diffusion is accompanied by cations (Na^+ , K^+ , Ca^{2+} , etc.) in the pore solution to maintain electroneutrality, and alkali ions more readily diffuse than divalent (calcium) ions due to the abundance of alkali ions in the pore solution and their smaller hydrated ionic sizes (Wang and Gillott 1991, Chatterji et al. 1986). There hydroxyl ions react with the silanol groups on the silica surface, accompanied by the attraction of alkali ions to the resulting negatively charged sites (Roy, 1986).

Alkali-Carbonate Reaction. General characteristics of an expansive alkali-carbonate reactive aggregate are: (1) a fine-grained calcite matrix; (2) rhombic dolomite crystals distributed in the calcite matrix; (3) the presence of clay, forming a network between the fine-grained calcite; and (4) the occurrence of a dedolomitization reaction (Gillot, 1975). The aggregates known to be susceptible to the expansive alkali-carbonate reaction are argillaceous dolomitic limestones, argillaceous calcitic dolostones

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and quartz-bearing argillaceous calcitic dolostones (Dolar-Mantuani 1983, p. 86). Dedolomitization reaction is the result of an attack of alkali ions on the dolomite constituent of the alkali-carbonate reactive aggregate, forming calcite, brucite and alkali-carbonate as reaction products (Gillott and Swenson 1969). Another possible expansion mechanism is the swelling action of initially dry (unwetted) clay in a dense matrix of the aggregate by absorbing moisture which reaches the clay through 'openings' commonly provided by the dedolomitization reaction (Gillott 1975).

Slow- and Late-Expanding Alkali-Silica/Silicate Reaction. The aggregates found to be susceptible to slow/late-expanding alkali-silica/silicate (SLEASS) reaction are a wide variety of quartz-bearing rocks with highly strained quartz: greywackes, argillites, quartzwackes, quartz-arenites, quartzites, hornfels, quartz biotite gneiss, granite, phyllite, arkose, and sandstone, but relatively unlikely in the rocks being studies here.

EXPERIMENTAL METHODS

Accelerated Tests and Other Auxiliary Tests. As for short-term accelerated tests, an accelerated test using concrete cores (Accelerated Concrete Core Method), proposed by Hudec and Larbi (1989), similar to the NBRI test, was used to test both alkali-carbonate reactivity and alkali-silica reactivity, and the accelerated mortar bar test (ASTM P 214, 1990) to test alkali-silica reactivity. A quick chemical screening test for potential alkali-carbonate reactivity (Rogers 1985a, 1986) was conducted for the coarse aggregate. In addition, the coarse aggregate powder was digested in an accelerated test condition (1.0 M NaOH and 80°C) to study the clay mineral phases. Additional experimental details are given in Lee (1993).

Long-Term Standard Test. The Canadian Standards Test Method CSA A23.2-14A (Concrete Prism Expansion Method) (CSA 1990a) was selected offering a high degree of confidence to detect alkali-carbonate reactive aggregates, and is also widely used for alkali-silica reactive aggregates.

Reference Aggregates. In conducting the alkali-aggregate reactivity tests, samples consisting of reference reactive aggregate, reference non-reactive aggregate, or their combination were tested as control samples in parallel with the aggregates being tested. Pittsburg quarry aggregate, well known alkali-carbonate reactive dolomitic limestone from Kingston, Ontario, Canada, was used as the reference alkali-carbonate reactive coarse aggregate, and Nelson aggregate, a quarried dolostone from Burlington, Ontario, Canada, as the reference non-reactive coarse aggregate. Both aggregates were from the stockpiles of known reactive and non-reactive aggregates maintained at the Ontario Ministry of Transportation, Canada.

Field Concrete Samples. In addition to the three different groups of field concrete samples prepared during the construction of the three tumulus pads, a couple of batches—approximately 5 yd³ of each batch—of an experimental silica fume concrete were poured at the Harrison Ready Mix plant in Oak Ridge, Tennessee. The mix design of the experimental silica fume concrete is given in Lee (1993), as are many other experimental details.

Sample Preparation. The test procedures for the accelerated test proposed originally by Hudec and Larbi (1989) were followed as closely as possible for the current testing, but slight modifications were made where applicable, as described in Lee (1993). The concrete mix was proportioned to have the water/cement ratio of 0.42, the sand/cement ratio of 1.6 and the total aggregate/cement ratio of 4.0. The original test procedures specify the alkali content of the concrete mix to be raised to 1.25% Na₂O equivalent by weight of cement of adding NaOH to the mix water. Since, as to be described in the following section, the concrete cores are stored in 1.0 M NaOH solution at 80°C while being tested, it is generally accepted that the initial alkali content of the mix has only a minor effect on the test results (Hooton 1990, 1992). Therefore, the addition of NaOH to raise the total alkali content was not practiced for the current testing. The component

materials so prepared were mixed according to the procedures in ASTM C 192 (1988). The cement used throughout was a local Dixie Type I/II Cement containing 0.11% Na₂O, 1.04% K₂O and 8.4% C₃A (Lee, 1993).

Accelerated Tests. After the core preparations, each group of four specimens from the same concrete block were soaked together in deionized water for four hours before the original (initial) specimen lengths were measured. The original length was used as the reference to calculate the length changes during the experiment. Each group of specimens was then stored in 400 g of 1.0 N NaOH solution in a 500 mL air-tight autoclavable polypropylene bottle and placed in an 80°C oven. The specimens were taken out of the oven every 48 hours and allowed to cool to room temperature. Specimens were then removed from the solution and surface-dried, and their lengths were measured. After the length measurements, they were returned to the solution, and the bottles were capped tightly and returned to the oven. One experimental run consisted of at least 15 measurements, i.e. 30 days of exposure to the hot alkali conditions.

Length Measurements. A simple comparator with a dial indicator of graduations of 0.0001 in. was used for length change measurements of specimens. Later a new comparator (0.00005 in.) adjustable to accommodate longer specimens was used, as described in ASTM C 490 (1988).

Expansion Limits. The critical expansion limit of a sample containing alkali-carbonate reactive aggregate has been proposed as 0.162% in 24 days, beyond which the aggregate is considered deleteriously reactive to alkali. The expansion limit was determined by correlating expansion data from the accelerated test of alkali-carbonate reactive aggregates to those from the Canadian concrete prism test (Hudec and Larbi 1989). The critical expansion limit proposed for alkali-silica reactive aggregate is 0.171% in 6 days or 0.30% in 12 days.

Digestion of Alkali-Carbonate Reactive Aggregate Powder in the Accelerated Test Condition. To further study causes of a moderate expansion of Rogers coarse aggregate shown by the accelerated concrete core test, the coarse aggregate powder was digested under the accelerated test condition (1.0 M NaOH solution at 80°C), and clay mineral phases of the coarse aggregate, after being exposed for certain periods of time to the 'hot' and highly alkaline environment, were studied by XRD. In addition Pittsburgh aggregate was studied in parallel as the reactive reference. To ensure a representative sampling, the coarse aggregate was crushed and thoroughly mixed using only those particles passing No. 4 sieve and retained on No. 8 sieve. The ground aggregate powder (10 g) along with 30-40 g of concrete pieces was immersed in 1.0 N NaOH solution in an 150 mL tightly capped plastic bottle and kept in an 80°C oven for 7, 14, and 24 days. After a specified period of digestion, the bottle was taken out of the oven and left to cool to room temperature. The digested aggregate powder was then washed with deionized water to remove excess salts, centrifuging and decanting the clear supernatant liquid. The aggregate powder was then dried in an 80°C oven and mixed thoroughly. A small portion of it was saved for XRD analysis.

Carbonate constituents of both undigested and digested aggregate powders were removed by dissolving the powder in 1.0 M Na-acetate solution adjusted to pH 5. The dissolution was conducted in about 300 mL of the Na-acetate buffer solution in a beaker with a cover glass on it. The solution was heated at 50°C on a hot plate and stirred with a magnetic stirring bar during the dissolution for one day. The residue was centrifuged and dissolved again in about 200 mL of fresh Na-acetate buffer solution by heating and stirring until there were no bubbles forming in the solution. After final centrifuging, the residue was then dried in an 80°C oven and mixed thoroughly.

Accelerated Mortar Bar Alkali-Silica Reactivity Test (ASTM P 214). The alkali-silica reactivity of Rogers natural silica sand (D08) was tested by the ASTM P 214 accelerated mortar bar test (ASTM P 214 1990). It has been shown that the results of ASTM P 214 accelerated tests conducted on various known alkali-silica reactive

aggregates closely resemble those of ASTM C 227 (Hooton 1990). Sample preparations for the accelerated test are essentially same as those of ASTM C 227 (1991). If the mean expansion of the test mortar bars is less than 0.10% at 14 days in 1.0 M NaOH solution at 80°C (16 days after casting), the aggregate is considered innocuous while if the mean expansion exceeds 0.20% at 14 days in the NaOH solution, it is considered deleteriously expansively reactive to alkali. If the mean expansion is above 0.1% and less than 0.2% at 14 days in the NaOH solution, ASTM P 214 (1990) suggests that the results are not yet conclusive.

Canadian Standards Test. The current testing for CSA A23.2-14A was conducted following the standard test procedures as much closely as possible; in some occasions, slight modifications of the test procedures were made to accommodate the current testing needs (Lee, 1993). The concrete prisms were cured above water at 25°C in large plastic containers equipped with a tightly fitting cover. Blotting paper was placed around the inside wall of the containers to provide a uniform moist condition. After 24 hours the concrete prisms were demolded. Immediately after demolding, the prisms were immersed in tap water at 23°C for 30 minutes before their initial (reference) lengths were measured immediately upon removal from the water. The length measurement were conducted with a comparator equipped with an electronic indicator with a repeatability of 0.00005 in. and a measurement range of 1.0 in. In the current testing, the concrete prisms, following the reference length measurements, were stored above water at room temperature (about 25°C) in a large plastic container with a tight-fit cover. Blotting paper was placed around the inside wall of the container to provide a uniform moist condition. The concrete prisms were measured for their length changes at 1, 2, 4, 8, 12, 16, 20, 24, 32, 40 and 52 weeks of moist storage at 25°C. Then, the concrete prisms were continuously tested in 38°C and moist condition by placing the plastic containers containing the concrete prisms in a large 38°C environment chamber. The concrete prisms were measured for their length changes at 4, 12, 24, 36 and 52 weeks of moist storage at 38°C. The testing at 38°C was to accelerate, if any potential remains, residual expansion due to alkali-aggregate reaction.

Test Runs. A total of five groups of concrete prisms, each group consisting of 3 x 3 x 14 in. concrete prisms, were prepared for the current tests. Combinations of coarse and fine aggregates of each group are listed below:

- Sample D13+OTT: three concrete prisms containing Rogers coarse aggregate (D13) and Ottawa sand (OTT); this sample is the target sample to test the alkali-carbonate reactivity of Rogers coarse aggregate;
- Sample D13+D08: three concrete prisms containing Rogers coarse aggregate (D13) and Ottawa sand (D08); this sample is for studying the effects of the alkali-silica reactivity of Rogers natural sand on the reactivity of Rogers coarse aggregate;
- Sample D13+D10: three concrete prisms containing Rogers coarse aggregate (D13) and Rogers manufactured dolomitic sand (D10); this sample is for studying the effects of Rogers manufactured sand on the reactivity of Rogers coarse aggregate;
- Sample PIT+OTT: three concrete prisms containing the reference alkali-carbonate reactive Pittsburg coarse aggregate (PIT) and Ottawa sand (OTT); this sample represents the reactive control; and
- Sample NEL+OTT: three concrete prisms containing the reference non-reactive Nelson coarse aggregate (NEL) and non-reactive Ottawa sand (OTT).

Microscopic Examination. After being tested for one year by the Canadian Standards concrete prism expansion test, specimens for microscopic examination were prepared from one concrete prism from each sample, which showed the medium expansion among the three prisms. The polished sections of the specimens were studied by scanning electron microscopy (SEM) and reflectance optical microscopy.

RESULTS AND DISCUSSION

Quick Chemical Screening Test for Alkali-Carbonate Reactivity. The results of the quick chemical screening test for alkali-carbonate reactivity of Rogers coarse aggregate show the CaO: MgO weight percent ratio and Al_2O_3 weight percent of Sample No. 1 are 16.1 and 1.55%, respectively, and those of Sample 2 are 16.6 and 1.45%, respectively; these are placed on about the borderline of the field in which potentially expansive alkali-carbonate reactive aggregates fall (Rogers, 1985a).

Accelerated Concrete Core Test. The results of alkali-carbonate reactivity of Rogers coarse aggregate (D13), tested by the accelerated concrete core method, are given in Fig. 1., in which those of the reference alkali-carbonate reactive Pittsburgh coarse aggregate (PIT) and those of the reference non-reactive Nelson coarse aggregate (NEL) are also shown.

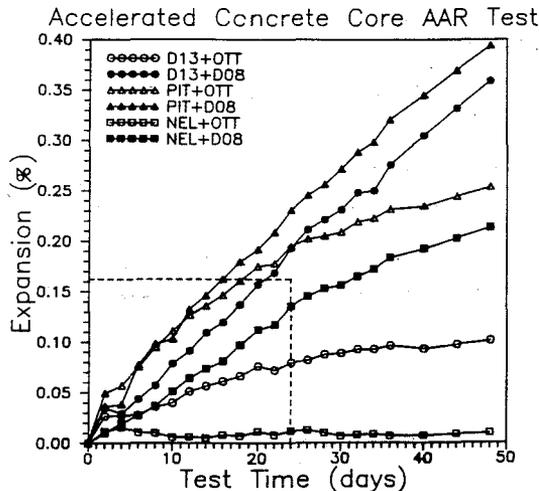


Fig. 1. Results of the Accelerated Concrete Core Alkali-Aggregate Reactivity Test for the Effects of Rogers Natural Sand (D08) on the Reactivity of Rogers Coarse Aggregate (D13). Pittsburgh Coarse Aggregate (PIT) and Nelson Coarse Aggregate (NEL) were used as the reference alkali-carbonate reactive and the reference non-reactive aggregate, respectively; Ottawa Sand (OTT) was used as the reference non-reactive fine aggregate.

The reference non-reactive Ottawa natural silica sand (OTT) was used as an inert fine aggregate for the samples. The dashed lines in the figure indicate the critical expansion limit of 0.162% in 24 days for a sample containing deleteriously expansive alkali-carbonate reactive coarse aggregate. The sample designations used to present the results of alkali-aggregate reactivity tests are illustrated in Table I. Numerical data of the length change measurements of various samples tested by the accelerated concrete core test method are given in Lee, 1993.

As shown in the figure, virtually no length change was observed in the non-reactive control sample (sample NEL+OTT) consisting of Nelson coarse aggregate and Ottawa sand. The reactive control sample consisting of Pittsburgh coarse aggregate and Ottawa sand (sample PIT+OTT) showed significant expansions, producing 0.178% expansion at 22 days that is close to the critical expansion limit, while the sample containing Rogers coarse aggregate (sample D13+OTT) shows an intermediate expansion behavior.

The results of several other combinations are also given in Fig. 1. By comparing the expansions produced by sample D13+D08, sample D13+OTT, and sample NEL+D08,

Table I Sample Designations Used to Present the Results of the Accelerated and the Canadian Standards Alkali-Aggregate Reactivity Tests

Sample Designation	Description
<u>Coarse Aggregates</u>	
D13	Dolomitic limestone from Rogers Group, Oak Ridge, TN A local coarse aggregate used for tumulus concrete production
PIT	Pittsburg quarry aggregate, Kingston, Ontario, Canada Reference alkali-carbonate reactive dolomitic limestone
NEL	Nelson aggregate, Burlington, Ontario, Canada Reference non-reactive quarried dolostone
<u>Fine Aggregates</u>	
D08	Natural silica sand from Rogers Group, Oak Ridge, TN A local fine aggregate used for tumulus concrete production
D10	Manufactured dolomitic sand from Rogers Group, Oak Ridge, TN An alternate local fine aggregate for tumulus concrete production
D13S	Sand made in the laboratory from Rogers coarse aggregate (D13) and having the same particle size distribution as Rogers natural sand (D08)
OTT	Ottawa sand, Ottawa, IL
<u>Fly Ash</u>	
G26	ASTM Class F fly ash from Southeastern Fly Ash Co., Rogersville, TN
<u>Field Concrete Samples</u>	
Tumulus-II	Specimens cored from 6 x 12 in. field concrete cylinder(s) for the Tumulus II pad (30 % fly ash (G26) by weight of cement)
IWMF-No. 1	Specimens cored from 6 x 12 in. field concrete cylinder(s) for the IWMF tumulus pad No. 1 (30 % fly ash (G26) by weight of cement)
IWMF-No. 2	Specimens cored from 6 x 12 in. field concrete cylinder(s) for the IWMF tumulus pad No. 2 (9 % silica fume by weight of cement)
Exp-SF-I	Specimens cored from 6 x 12 in. field concrete cylinder(s) for the experimental silica fume concrete produced using Rogers manufactured sand (D10) (9 % silica fume by weight of cement); cast on 8/7/90
Exp-SF-II	Specimens cored from 6 x 12 in. field concrete cylinder(s) for the experimental silica fume concrete produced using Rogers manufactured sand (D10) (9 % silica fume by weight of cement); cast on 8/14/90

it is seen that significant expansions were contributed by Rogers natural sand. Sample D13+D08 expanded at a constant rate from the beginning to the end of the test, although expansion rates of sample D13+OTT (showing the expansion by D13 aggregate) and sample NEL+D08 (showing the expansion by D08 sand) decreased at later test days as noticed by the reduced slopes of the expansion curves at about 24 days.

The results of the combination of Rogers coarse aggregate (D13) and Rogers manufactured dolomitic sand (D10) that is an alternative fine aggregate for tumulus concrete, are given by sample D13+D10 in Fig. 2. Also included in the figure are the effects of replacement of Dixie cement (I22) by ASTM Class F fly ash (G26) (24% by weight) on the expansion of sample D13+D10 (shown by sample D13+D10+G26). The effects of replacing Rogers natural sand (D08) with another manufactured sand (D13S), made in the laboratory with crushed Rogers coarse aggregate (D13) and having the same size distribution in Rogers natural sand, are given by sample D13+D13S, along with the effects of fly ash replacement shown by sample D13+D13S+G26. As shown in Fig. 2, sample D13+D13S showed about the same expansion as that of sample D13+OTT. About 50% reduction in expansion in sample D13+D10+G26 and about 30% reduction in sample D13+D13S+G26 both at 24 test days were obtained by the fly ash replacement, compared respectively to the expansions produced by sample D13+D10 and sample D13+D13S at the same test day.

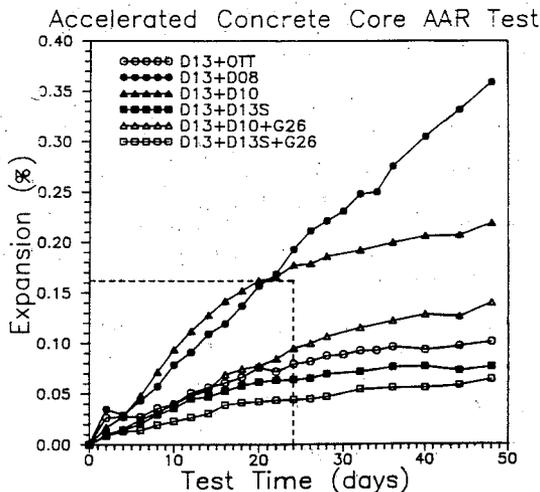


Fig. 2. Results of the Accelerated Concrete Core Alkali-Aggregate Reactivity Test for the Effects of Different Fine Aggregates and Fly Ash Incorporation on the Reactivity of Rogers Coarse Aggregates (D13).

Although the coarse aggregate gradings and mix designs of field concrete samples are different from those specified by the accelerated test procedures; specimens cored from selected field concrete samples (6 x 12 in. cylinder) of different groups were tested by the accelerated test for a qualitative study, and the results are given in Fig. 3. The obvious trends are that field concrete samples containing Rogers natural silica sand (D08) showed continued expansions from the beginning to the completion of the test, and the combined expansions are apparently mainly due to the alkali-reactivity of the sand. The expansions and the rates of field concrete samples were however much less than those of the laboratory-prepared sample D13+D08, and the reduction is believed to be due to the incorporation of fly ash in samples Tumulus-II and IWMF-No. 1, and of silica fume in sample IWMF-No. 2. One interesting result is that samples from the experimental silica fume concretes batched using Rogers manufactured sand (samples Exp-SF-I and Exp-SF-II) showed only a slight expansion, both producing only about 0.03% expansion at 24 days and no further appreciable expansions beyond 24 days.

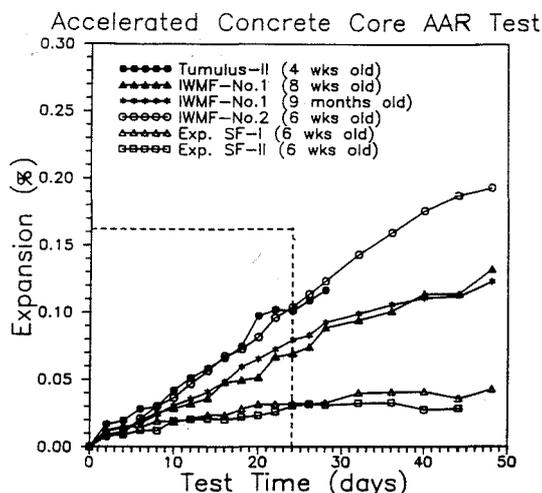


Fig. 3 Results of the Accelerated Concrete Core Alkali-Aggregate Reactivity Test for Various Field Concrete Samples. Ages of the Field Samples when the Test Initiated are Indicated in the Parentheses.

Considering the expansions produced by the laboratory-prepared sample D13+D10, silica fume was very effective in reducing the expansion. However, the effects of silica fume were seen to be much less in the sample containing Rogers natural sand (sample IWMF-No. 2). Due to lack of space, the results of the accelerated mortar bar list and the Concrete Prism test are not reported here, but are described in Lee (1993). The mortar bar test showed expansion of the natural silica sand, while the concrete prism test showed marginal expansion of specimens containing the sand, at three months, but well below the allowed limit at one year.

Microscopic Studies. Secondary electron images were made of particles of Ottawa natural silica sand used in samples D13+OTT and PIT+OTT. After accelerated testing these are relatively clean and intact, and showed no sign of significant deterioration of the sand particles due to alkali attack. However, porous and internally granulated (fractured) features of Rogers natural silica sand (D08) grains were found under the same conditions. The sand grains are covered with alkali-silica gels and some crystalline materials, and the pores and fractures (or cracks) are partially filled with the gels. The observations are in parallel with the continued expansion behaviors at constant expansion rates shown by all samples containing the sand. Formation of massive alkali-silica gels like those shown in Fig. 4 was observed in air-voids and other empty space in samples D13+D08 and PIT+D08. Energy dispersive X-ray (EDX) analysis indicated that the massive gels consist mostly of Si, some Al and Ca, and a small amount of Na.

X-Ray Diffraction Studies. Patterns of digested samples (not shown) suggested that a dedolomitization reaction occurred. Additional observations were made on the clay mineral fraction. XRD patterns of Mg-saturated, ethylene glycol-solvated acid insoluble residue of Rogers coarse aggregate powder, undigested and digested for 7, 14 and 24 days, are compared in Fig. 5. The comparison of the peaks clearly shows the gradual development of expansible clay minerals (vermiculites/smectites) at the expense of chlorite as digestion continues. In the 24-day digested acid insoluble residue, the 14Å peak is barely seen. It is also shown that illite is very resistant to the digestion condition as evidenced by no appreciable changes in the intensity of the 10Å peak with digestion. It is therefore concluded from the XRD analysis that, during the digestion periods, the low-charged vermiculite initially present transformed to smectite; the high-charged vermiculite initially present transformed to low-charged vermiculite, then

possibly to smectite; much of the chlorite initially present transformed to vermiculite/smectite.

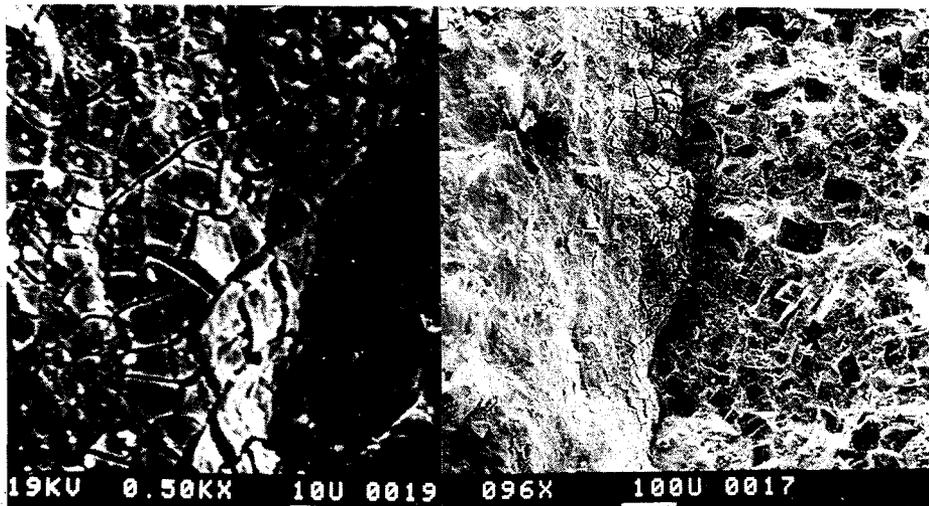


Fig. 4 SEM Micrographs Showing Massive Alkali-Silica Gels Formed in Contact Zone of Dolomitic Limestone with Mortar in Concrete Cores Containing Rogers Natural Sand After Accelerated Concrete Core Alkali-Aggregate Reactivity Test.

SUMMARY AND CONCLUSIONS

By a combination of experiments, the Rogers coarse aggregate is shown to be marginally alkali-expansive, but can be considered generally comparable to that of the reference non-reactive Nelson aggregate. The occurrence of expansive alkali-carbonate reactive aggregate in Tennessee and Virginia areas had been reported (Luke 1963, Sherwood and Newlon 1964). The alkali-carbonate reactive dolomitic rocks found in Tennessee were from a quarry in the Chickamauga limestone formation, and the rocks were used for a concrete structure of the Chickamauga Dam Powerhouse near Chattanooga, Tennessee. The reported expansions in the concrete structure were relatively minor but enough to create difficulty for holding power generating equipment in line (Luke 1963). The Chickamauga formation includes several members that have been studied in Virginia (Sherwood and Newlon 1964) and found to contain beds susceptible to alkali-carbonate reaction (Luke 1964).

It is unlikely that Rogers natural silica sand could cause deleterious expansion and distress of field concrete unless the concrete is exposed to a highly alkaline environment at elevated temperatures for prolonged periods. However, since the concrete is used to contain radioactive materials, and the potential impacts of the physical characteristics of the sand grains (porous and granulated, or internally fractured) on the long-term durability of the concrete are not clear, it would be advisable to exercise precautions. Field performance records of the sand, if available, would be valuable in projecting the long-term performance of the sand in concrete.

The test conditions (1.0 M NaOH solution at 80°C) employed by the accelerated concrete core alkali-aggregate reactivity test and the ASTM P 214 accelerated mortar bar alkali-silica reactivity test may be too aggressive, and the tests that were developed using the known reactive and non-reactive aggregates can give an exaggerated alkali-aggregate reactivity for some siliceous aggregates which have some degree of reactivity but are considered satisfactory.

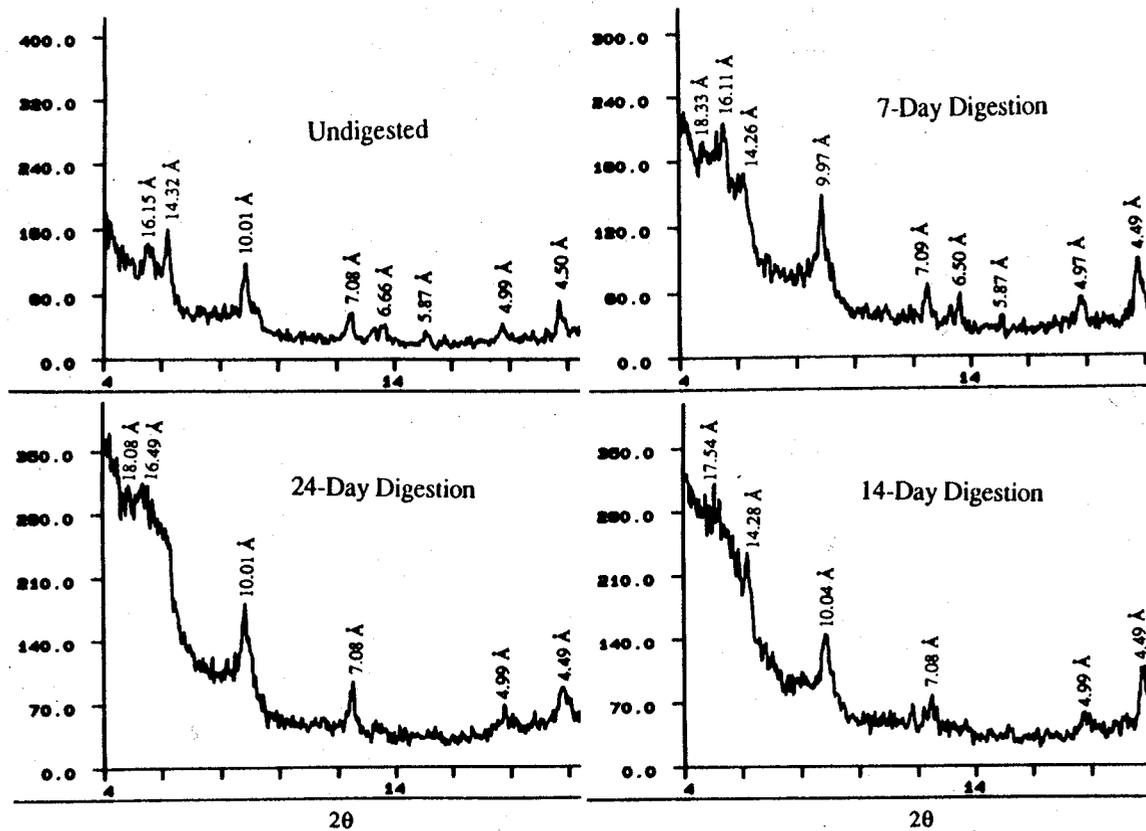


Figure 5 XRD Patterns of Mg-Saturated, Ethylene Glycol Solvated Acid Insoluble Residue of Rogers Coarse Aggregate Powder, Undigested and Digested for 7, 14 and 24 Days

The degrees of expansion produced by reaction of alkalis with carbonate aggregates in concrete are more influenced by the characteristics of the rock textures and contents of reactive dolomite components than the types of clays present. Although accelerated reaction studies could generate both a dedolomitization reaction, and the formation of expansive clays from non-swelling clays, it is not clear which was likely to dominate in the current rocks. The most expansive of the local aggregates studied was obviously the natural silica sand.

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