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# MICROSCOPIC OBSERVATION OF THE PRODUCTS OF THE ALKALI-SILICA REACTION IN THE DYED THIN SECTIONS OF CONCRETE CORES

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## SYNOPSIS

The products of the alkali-aggregate reaction could be distinguished from the components of the concrete by microscopy after dyeing these. Cyanoacrylate mixed with a coloring substance was used to dye the alkali-silica gel red. Cyanoacrylate reacts readily with water contained in the gel but not with the components of the concrete. Examination of dyed thin sections revealed a few concrete cores with expansion of alkali-silica reactive aggregates. This method appears to be useful for observing the alkali-aggregate reaction.

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## 1. Introduction

Recently many workers have reported the occurrence of durability failure of concrete due to the alkali-aggregate reaction in Japan [1]-[7]. Almost all the rocks and minerals known to be alkali-expansive in Japan fall into the alkali-silica reaction, while alkali-aggregate reactions are subdivided into three categories, the alkali-silica, the alkali-carbonate-rocks and the alkali-silicate reactions. All of the concrete affected by a deleterious alkali-silica reaction contains deposits of gel in voids, cracks, and aggregate particles. Studies on the growth of gel or occurrence of concrete cracking due to alkali-silica reaction are very important in understanding the mechanism of the reaction and to recognize the expansive rocks and minerals. Although pockets of gel in cracks and voids are frequently visible to the naked eye, most of them occur as microcracks within and adjacent to particles of expansive aggregate or cement paste, which are observed under a microscope [8]-[11]. However, a clear distinction between gel and components of concrete in thin and polished sections is in trouble because gel is usually translucent, white and isotropic microscopically.
Herein we report that the products of the alkali-silica reaction could be distinguished from the components of concrete under a microscope after dyeing the gel. Cyanoacrylate mixed with a coloring substance was used to dye the gel and cracks within the concrete.

## 2. The preparation of dyed thin section

### 2.1 The selection of coloring substances

We prefer coloring substances which have the following characteristics: (i) to dye the gel and cracks but not the other components of the concrete, (ii) to be an excellent bond, (iii) to penetrate into depth from the surface of concrete, (iv) to be miscible with dyestuffs. Therefore, we considered that cyanoacrylate of many bonds is the most suitable bond for the present examination. Cyanoacrylate which is a less viscous material, reacts readily with water contained in the gel, but not with

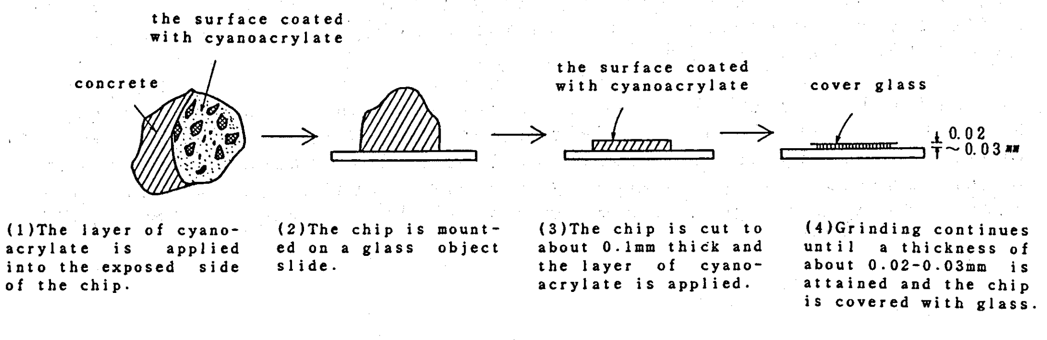


Fig. 1 Technical procedure for the dyed thin section.

components of concrete. It partially and completely fills the cracks and voids in concrete. Since cyanoacrylate on the market is a colorless transparent liquid, we tested cyanoacrylate mixed with red, blue or opaque dyestuffs, and found that red is the best dye.

### 2.2 The technique used for the preparation of dyed thin sections

In general, a common form of microscopic examination employed for transparent materials, involves the use of thin sections which are usually about 0.03mm thick. Dyed thin sections are made by the following procedure, which is modified from the technique employed for ordinary thin sections. A smooth surface of concrete affected by alkali-silica reaction, is cleaned and dried by using a hot plate (about 80 C) and then, a thin layer of cyanoacrylate is spread on it. The surface coated with cyanoacrylate is polished by utilizing successively 320 to 3,000 silicon carbide (grain). It is mounted on a glass object slide, and is cut to about 0.1mm thick. The exposed side of the mounted chip is again applied to a layer of cyanoacrylate. It is ground until a thickness of about 0.02-0.03mm is attained. When the section is ground to the proper thickness, it is covered with a cover glass (Fig.1).

## 3. A few cases of microscopic examination

The dyed thin section was examined under a microscope on concrete cores and mortar bars with expansion of alkali-silica reactive aggregates. As shown in photo 1,2 and 3, the reaction products dyed red were identified easily and distinguished into three types.

### 3.1 The reaction product within particles of expansive aggregates

The reaction products were found in pores and cracks in coarse aggregates. Each aggregate develops an irregular form of cracking. The products formed fillings of amebic shape and width of crack changes with the location very much in chert aggregates (photo 1 B, C and D). In photo 1 A the cracks in andesite aggregates traverse from one aggregate to another across cement paste and thier width is little changeable. Photo 1 E and F showns on alkali-reactive quartz in the thin section of granite. Quartz verges toward the reaction product. It indicates that the quartz grain is alkali-reactive. This expanded concrete involves chert, mudstone and granite aggregates.

### 3.2 The fillings of crack in cement paste and boundaries between cement paste and aggregates

Gel partially and completely fills the cracks in cement paste and boundary between cement paste and particles of chert, andesite and quartz. In photo 2 E the reactive products are abundant in the part of the crack touching the reacted particle of quartz but it is poor in the part of the crack in contact with the non-reactive feldspar particle. The contacting surface between quartz and cement paste is not clear (photo 2 D). These findings suggest that the particles of quartz are alkali-reactive.

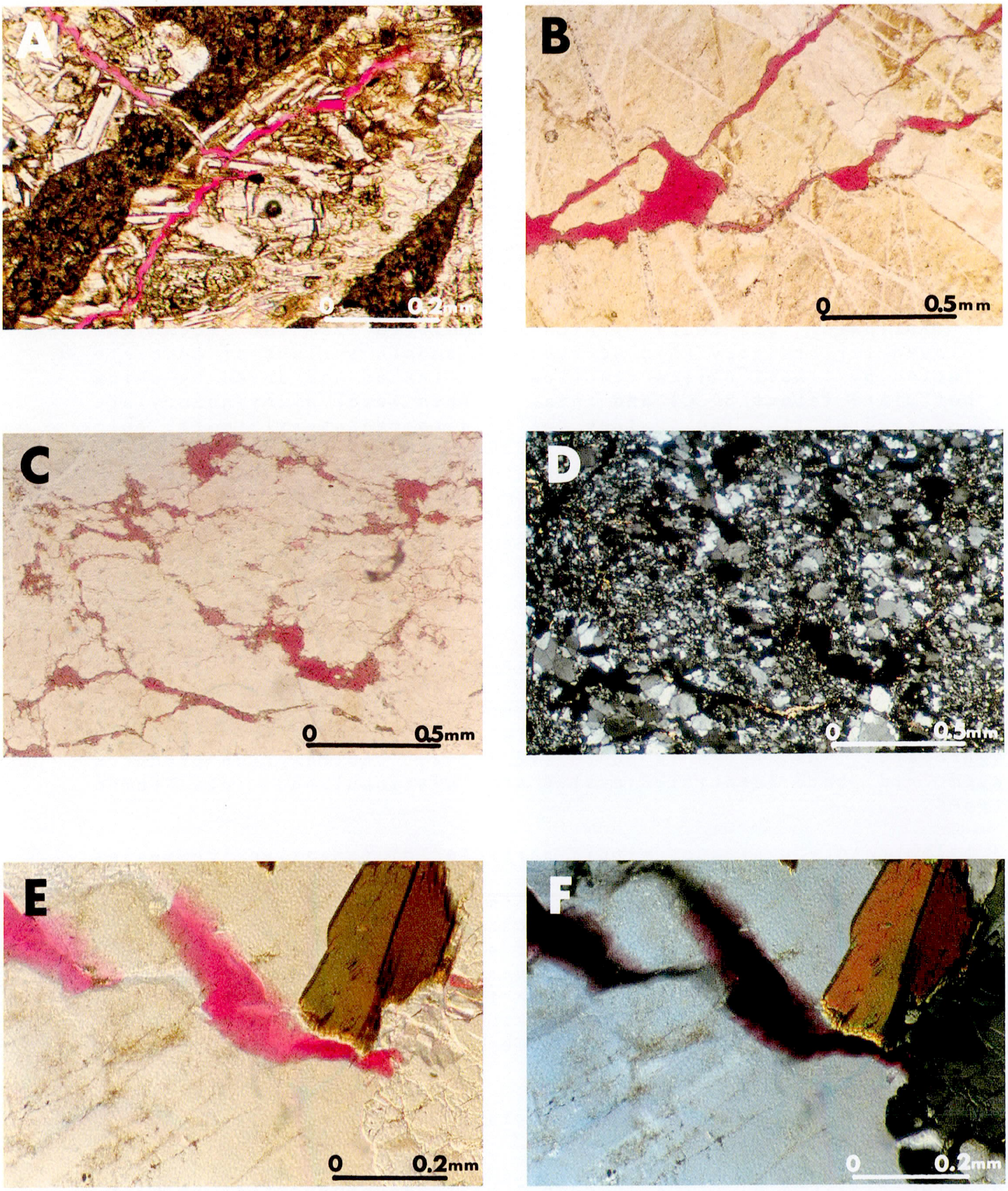


Photo 1 Products of the alkali-silica reaction in reactive aggregates.

A: Cracks in andesite particles filled with reaction products. Reaction ring is not detected on the margin of affected aggregates (mortar bar, sample MA-1, open nicol).
B,C,D: Reaction products of irregular shapes in chert aggregates regardless of grain size (expanded concrete, sample CA-3, B,C: open nicol, D: crossed nicols).
E,F: Reaction products in quartz of granite. Obscure boundaries illustrate dissolution of silica (expanded concrete, sample CA-1, E: open nicol, F: crossed nicols).

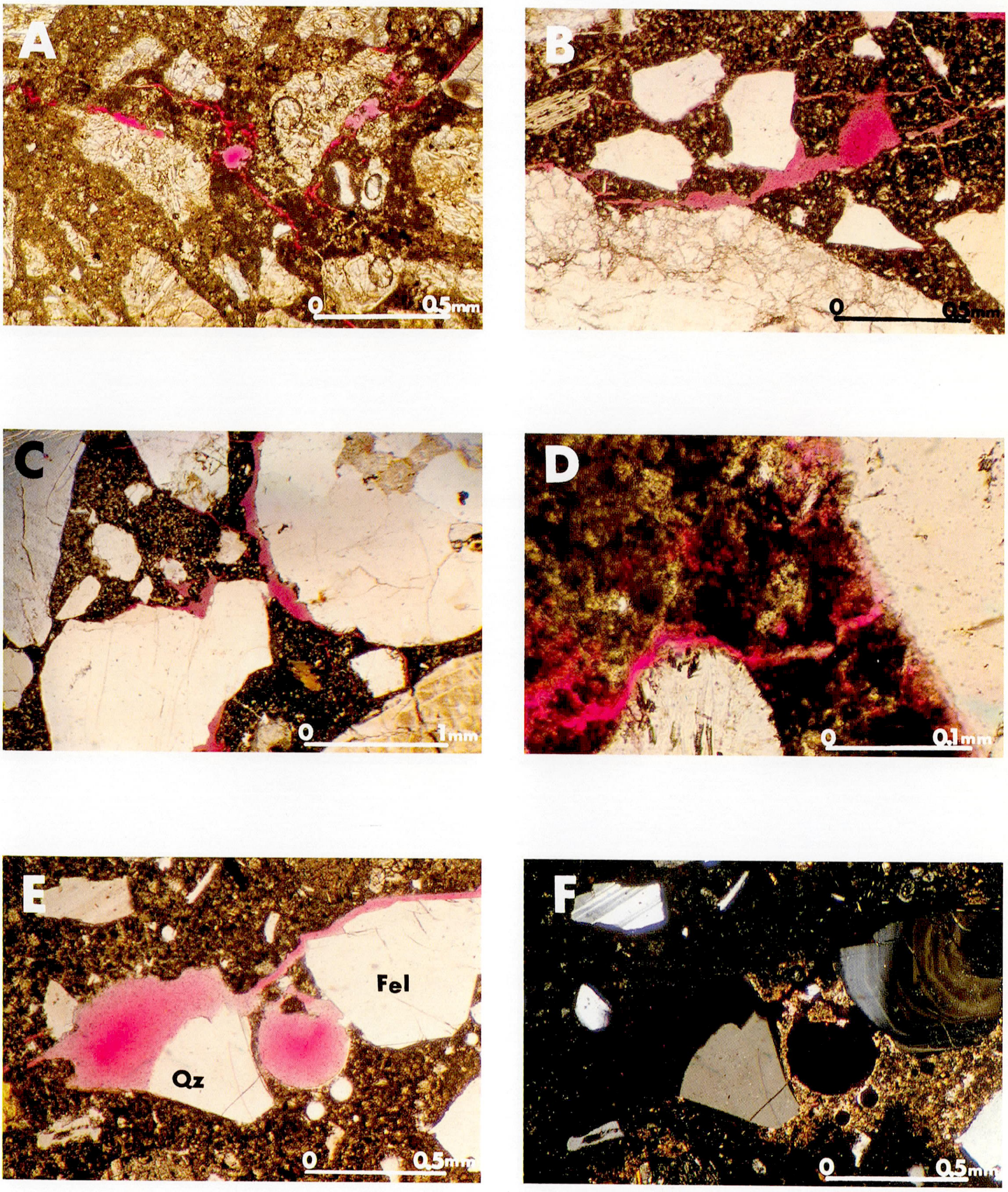


Photo 2 Products of the alkali-silica reaction filling the crack in cement paste and boundaries between cement paste and aggregates.

A,B: Irregular shape of reaction product found in cement paste and surroundings of aggregate (A: mortar bar, sample MA-1, open nicol, B: expanded concrete, sample CA-3, open nicol).
C,D: Reaction products on boundaries between quartz grain and cement paste. Photo D shows detail of obscure boundary. Silica was leached from the quartz particles (expanded concrete, sample CA-3, open nicol).
E,F: Crack in contact with reactive quartz and unreactive feldspar. Crack touching reactive quartz illustrates swelling of reactive product (expanded concrete, sample C-4, E: open nicol, F: crossed nicols).

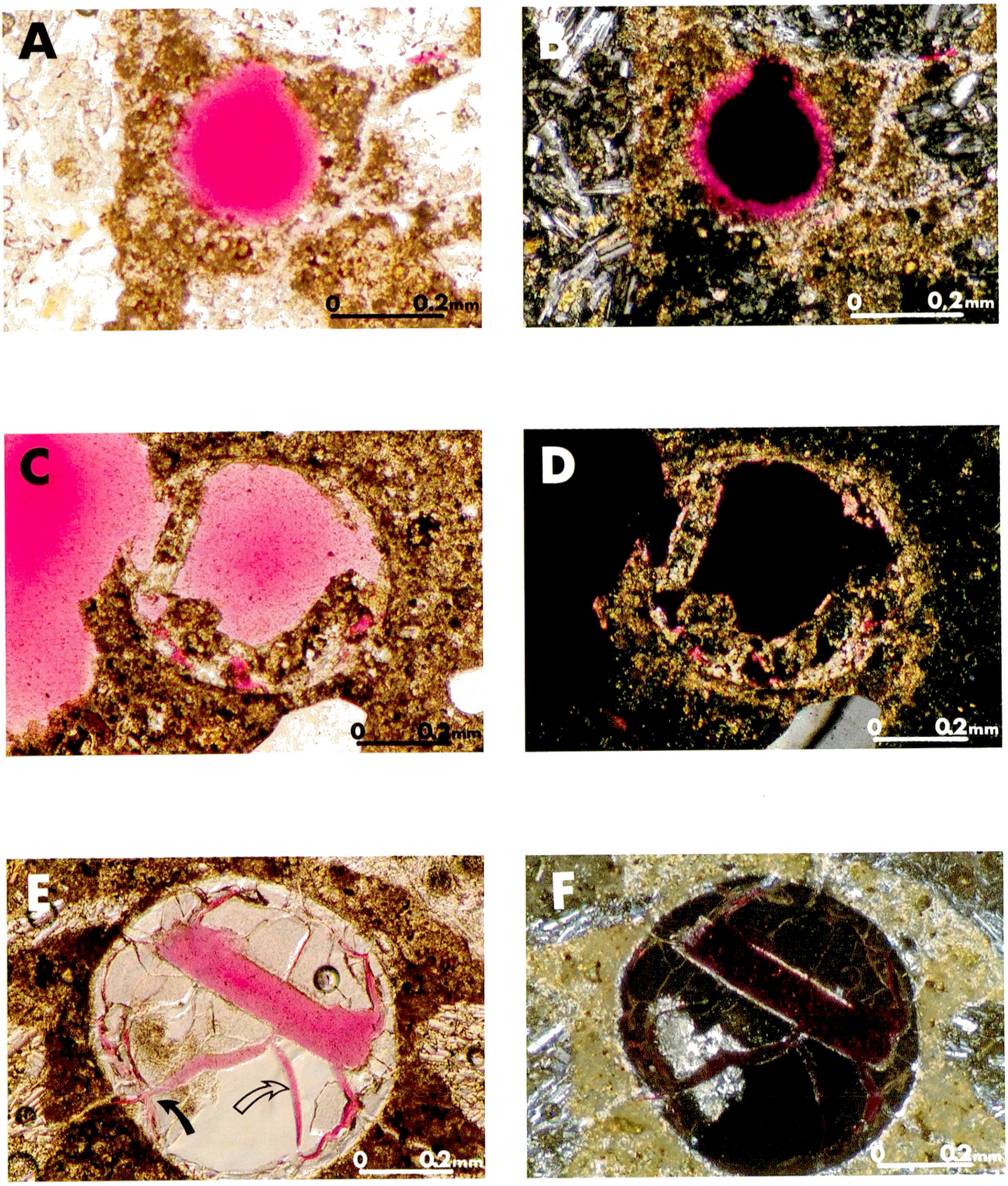


Photo 3 Spherical reaction products in cement paste.

A,B: Sphere filled with reaction product. Reaction zone is observed on the surrounding of sphere (mortar bar, sample MA-1, A: open nicol, B: crossed nicols).
C,D: Sphere composed of reaction products and microcrystalline matter (expanded concrete, sample C-4, C: open nicol, D: crossed nicols).
E,F: Spherical reaction products including shrinkage crack which was constructed as the gel dried (⇨) and crack which was formed based on expansion of gel (←) (mortar bar, sample MA-1, E: open nicol, F: crossed nicols).

### 3.3 The spherical reaction products in cement paste

When a void in concrete is filled with gel , a conspicuous sphere consisting of the reaction products is formed and micro-crystalline matter in or outward the spherule is observed. Two varieties of cracks, cracks in spherule and cracks which extend outside of spherule, were present. The former is a shrinkage crack which was constructed as the gel dried and the latter was formed based on expansion of gel (photo 3 C, D and F). There are many voids which contained no gel and were filled with cyanoacrylate alone. This type of void is distinguishable, based on the lack of microcrystalline matter around spherule and shrinkage space in the spherule as the cyanoacrylate dried.

## 4. Conclusions

The products of the alkali-silica reaction are dyed to differentiate the reaction products from the components of concrete easily. Cyanoacrylate mixed with a coloring substance was found to be the most suitable bond to dye the alkali-silica gel red. By the microscope examination of the dyed thin sections made from expanded concrete and mortar bar, various types of reaction products including cracks and spherules were identified and distinguished.

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