# THE IDENTIFICATION OF OPAL AND CHALCEDONY IN ROCKS AND METHODS OF ESTIMATING THE QUANTITIES PRESENT

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ABSTRACT

Opal and chalcedony are alkali-aggregate reactive minerals which when present in aggregates used in concrete may give rise to disruptive expansion. Opal and chalcedony mixtures in a form known as beekite have been found as secondary minerals in a suite of igneous rocks including granites, diorites, acid volcanic rhyolites and ultra mafic mica trapps, as a secondary mineral in a mixed suite of rocks from a gravel and opal as secondary material in limestones.

The quantities of beekite present in concrete cores from a structure and from samples of the aggregate used, have been determined by microscopic techniques using very large thin sections.

It has been shown that for rocks of similar porosities the expansion of concrete can be related to the proportion of opal present; the lower the porosity the greater the expansion. However there may be circumstances when after an increase in expansion with increasing opal content there may be a decrease in expansion with further increases in opal content.

## Introduction

The most alkali-aggregate reactive form of silica is opal; chalcedony, which is also pure $SiO_2$, is less reactive and leads to smaller expansion. Both of these minerals are extremely rare in igneous rocks and are then only present as secondary minerals.

Examples of opal and chalcedony in rocks from concrete structures which showed signs of movement, crazing and gel 'pop-outs' characteristic of alkali-aggregate interaction have been studied. Petrographic examination of the aggregates from the concrete showed them to be a mixture of igneous rocks in two examples, granites, diorites, ultra mafic hyperbyssal mica trapps and devitrified rhyolites being identified and of limestone in the third. Petrographic examinations have also been made on a fourth series of rocks which have not been used as concrete aggregates.

Since the expansion of the concrete may be related to the quantities of the reactive minerals (1), it was necessary to estimate the quantities of opal and chalcedony present. Petrographic microscopic techniques using large thin sections were used for this determination.

## Identification of Reactive Minerals in the Aggregate

Pieces of aggregate associated with typical surface gel (Figure 1) were removed from a concrete core from an affected concrete structure and subjected to petrographic examination. Opal and chalcedony mixtures in a form known as beekite were identified. Opal occurs as an isotropic material of low refractive index, n about 1.44. Chalcedony is often associated with the opal, it has a low birefingence about 0.009, refractive index $n\beta$ about 1.537.

Thin sections were also prepared from pieces of the aggregate used in the manufacture of the concrete and opal and chalcedony were identified as being present in the following rock types: granite, diorite, microgranite, brecciated felsite, porphyritic rhyolite and rhyolite. The opal and chalcedony which was always clearly secondary, occurred as vermicular growths (Figure 2), as massive material with globular opal set in clear chalcedony (Figure 3). This form of an intimate mixture of opal and chalcedony has become known as beekite although the name originally referred to a sedimentary chert from the Devonian limestones of Devon.

## Quantitative Estimation of Reactive Silica Minerals

Since the expansion of concrete is related to the amount of reactive mineral present some means of quantifying the proportion present in the aggregate is required.

Large thin sections about 30 micrometers thick and about 210 x 100 mm or 150 x 80 mm were prepared from either concrete cores or from a melange of quartered down single sized pieces of aggregate, 4 mm average diameter (Figures 4 and 5 respectively).

These large thin sections were then searched on a low power polarizing microscope magnification x13, for any suspect grains which were then marked. On completion of the search the section was transferred to a normal petrographic microscope and the marked grain examined more closely (Figure 6). If beekite was found then the proportion present in the grain was estimated by area measurement. For this work it is assumed that the area is directly proportional to the volume and that since the densities of the materials are similar the volume is proportional to the weight.

For concrete cores the paste proportion was determined as 20% so that after the area of beekite in the thin section was determined it was adjusted to allow for the paste present.

For the aggregate sample examined, all diorite, the slice contained about 750 grains, average size 16 $mm^2$.

Using the area proportioning technique of examining large thin sections the proportion of beekite in the core was determined as 0.025% and in the aggregate sample as 0.0035%.

## Relationship between Reactive Silica Content of Aggregate and Expansion

The expansion of concrete is related to the amount of alkalies present in the cement, the quantity of reactive silica in the aggregate, the form in which the reactive material is present, ie porosity and the quality of the concrete. Table 1 and Figure 7 give the data on a number of mortar bars made with basalt aggregate containing varying proportions of opal. The opal was from a malmstone with a porosity of 41.5%. The bars were made according to the method of Jones and Tarleton (2) and the cement was made up to contain either 0.7% or 1.2% combined alkalies ($Na_2O + 0.656\ K_2O$).

TABLE 1

Expansion at 140 Weeks of Low Quality Mortar Bars made with Aggregate Containing Varying Quantities of Opal

| % Opal | Expansion as percentage of length: Low alkali cement (0.70%) | Expansion as percentage of length: High alkali cement (1.2%) |
|---|---|---|
| 0.25 | 0.025 | 0.042 |
| 1.25 | 0.015 | 0.077 |
| 2.5 | 0.015 | 0.021 |
| 5.0 | 0.020 | 0.019 |

These results show that for the low alkali cement the expansion increases with increasing opal content, but with the high alkali cement the mortar bar expansion increases with increasing opal content up to about 1.25% opal and then decreases as the opal content is further increased.

Jones and Tarleton (2) examined a series of mortar bars using Siliceous magnesium limestone (SML) and Nebraska Gravel (NG) but no attempt was made by them to determine the quantity of opal present in the rocks. Using the techniques of area measurement of thin sections the quantities of opal present in these rocks has been determined and thereby the amount of opal present. The Siliceous magnesium limestone had a porosity of 6% and an opal content of 0.6% and the Nebraska Gravel had a porosity of 3% with an opal content of 0.125%.

Mortar bars were made by Jones and Tarleton using an inert basalt as a diluent and the results of expansion at 1 year when compared with opal content are given in Table 2. The results are plotted together in Figure 8.

TABLE 2

Expansion in Percent of Length of Poor Quality Mortar Bars at 1 Year (Cement contains 1.2 Per Cent Combined Alkalies)

| Per Cent Opal | Expansion % |
|---|---|
| SML | |
| 0.03 | 0.032 |
| 0.15 | 0.18 |
| 0.30 | 0.42 |
| 0.60 | 0.78 |
| NG | |
| 0.006 | 0.017 |
| 0.013 | 0.017 |
| 0.025 | 0.022 |
| 0.06 | 0.027 |

New experiments have also been carried out on granitic rocks, porosity about 3% which were estimated to contain various quantities of beekite. The expansion at 1 year using mortar bars made to the Jones and Tarleton specification are given in Table 3.

TABLE 3

Expansion in Percent of Length of Poor Quality Mortar Bars at 1 Year (Cement contains 1.2 Per Cent Combined Alkalies)

| Per Cent Beekite | Expansion % |
|---|---|
| 0.00 | 0.015 |
| 0.004 | 0.021 |
| 0.025 | 0.03 |

These have also been plotted as a combined graph in Figure 8.

The effect of porosity of the opal bearing rocks can be seen by comparing the results of the porous malmstone (porosity 41.5%, 0.25% opal, expansion 0.042%) with the results from Siliceous magnesium limestone (porosity 6%, 0.3% opal, expansion 0.42%). The highly porous malmstone had, for a similar quantity of opal only one tenth of the expansion of the less porous limestone. The probable explanation for this is that the sodium silicate gel which is the expansive agent is absorbed in the pores of the highly porous rock and is not available for expansion. For the aggregates of lower porosities, all the results of expansion with similar mortar bars show a similar relationship and may be plotted on one graph, Figure 8.

## Conclusions

Opal and chalcedony have been identified as secondary minerals in igneous rocks. The quantities of these minerals may be estimated by area measurement of thin sections of either concrete or aggregate particles.

If the rocks have similar porosities, then the expansion of mortars made with similar cements of high alkali contents will be related to the quantities of reactive silica present.

## Acknowledgement

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## References

1 N M Plum, E Poulson and G M Idorn, Ignenionen, 27, 1957, 1-2.

2 F E Jones and R D Tarleton, Reactions between aggregates and cement, Part VI, Alkali aggregate interaction. National Building Studies, Research Paper No 25, HMSO, London 1958, 1-64.

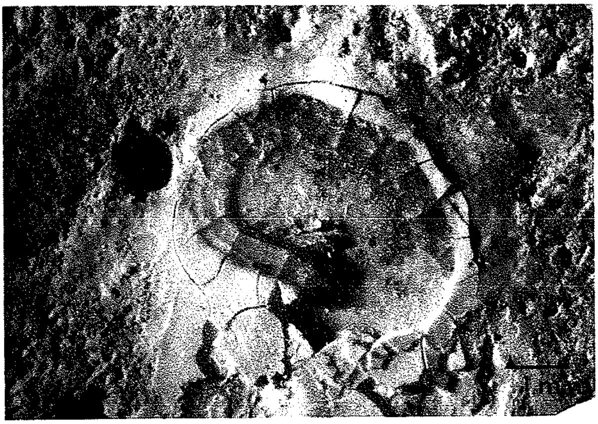

Fig 1 Gel formed on surface of concrete core stored in 100% RH for 1 month.

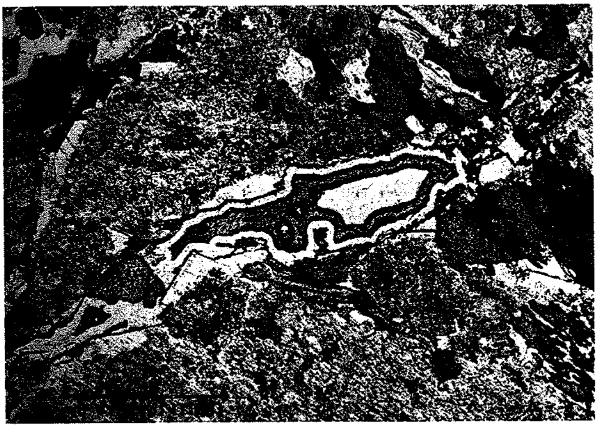

Fig 2 Optical micrograph of vermicular opal and chalcedony in diorite.

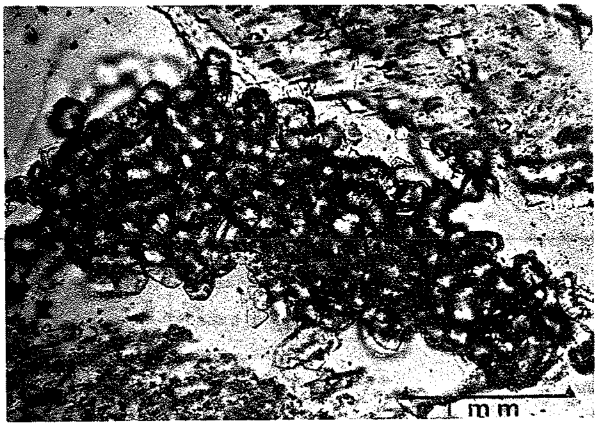

Fig 3 Optical micrograph of globular opal in diorite.

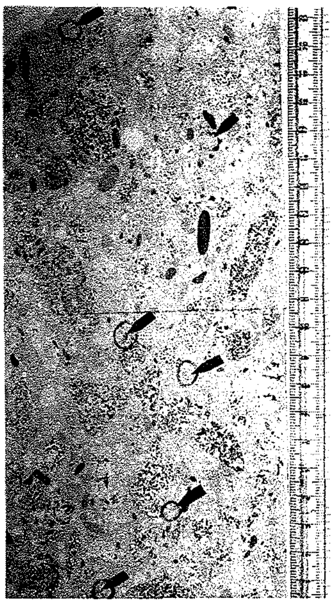

Fig 4 Low power photomicrograph of thin section of concrete core with marked suspect grains.

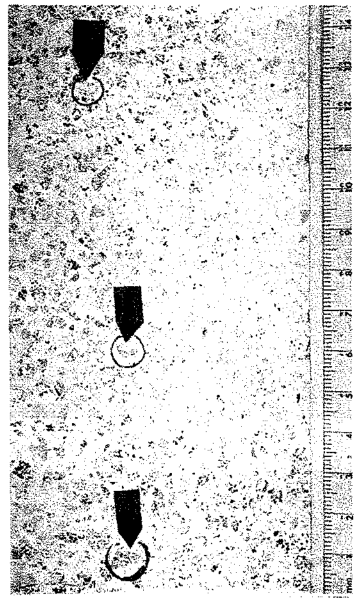

Fig 5 Low power photomicrograph of thin sections of aggregate particles with marked suspect grains.

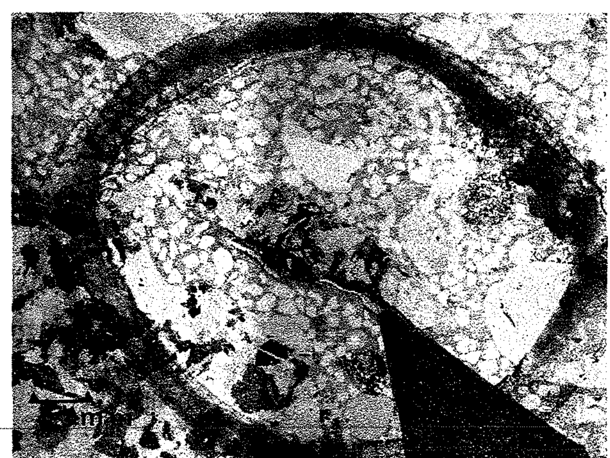

Fig 6 Optical micrograph of suspect grain from cements core.

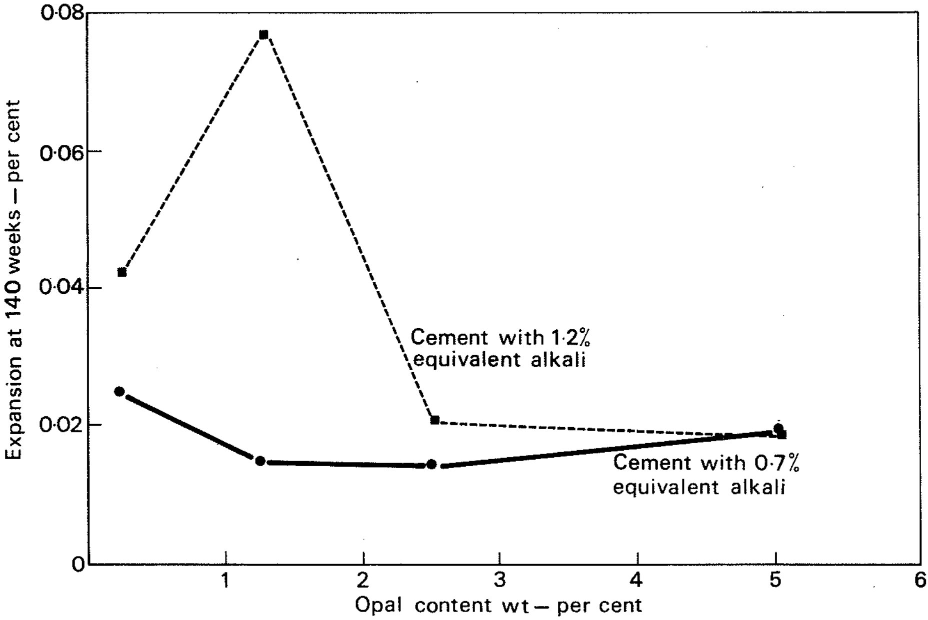


**Figure 7** Relationship between opal content of aggregate and expansion at 140 weeks for poor quality mortars, made with cements of different alkali contents

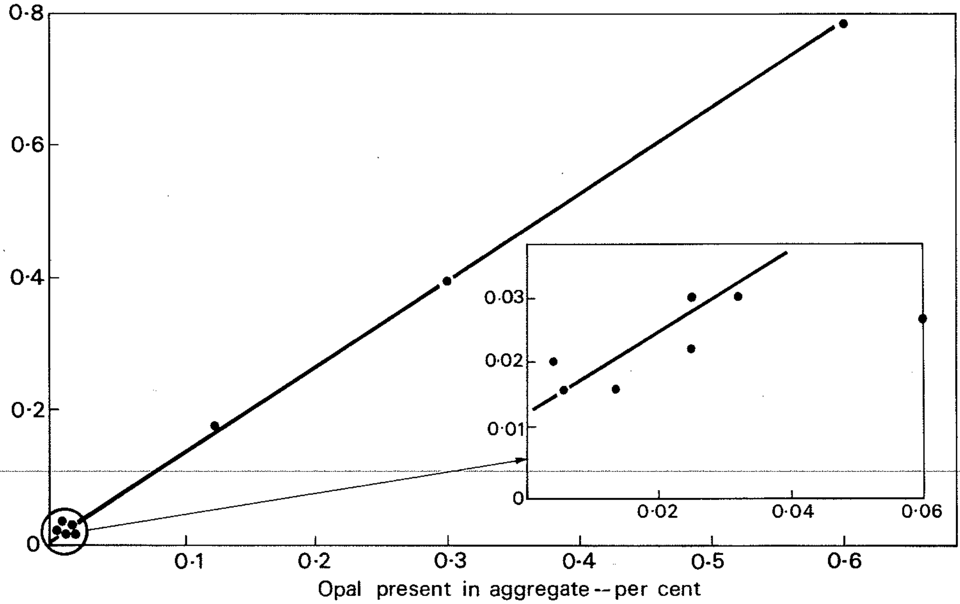


**Figure 8** Relationship between opal content of aggregate and expansion at 1 year, for rocks with low porosity