The Reactivities of Fine-Grained Quartz in Rapid Tests and in Concrete

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ABSTRACT

Confusion has been generated about the alkali reactivity of fine-grained quartz and its capacity to cause disruptive expansion and deterioration of concrete. Despite various test reports which indicate that this component of some aggregates can undergo significant chemical reaction,its performance in concrete has been variable and generally less severe than expected and in some instances it has caused neither significant aggregate reaction nor concrete deterioration. Consequently caution is needed when interpreting test data concerning the reactivity of fine-grained quartzes. A detailed petrographic examination and,when this examination shows the need,a determination of the amount of crypto-crystalline quartz in the fine-grained quartz component are essential. Further, confirming evidence of deleterious reactivity and disruptive expansion must be obtained from mortar and concrete tests.

INTRODUCTION

Adequate test data and field experience are available to show and prove the reactivity potentials of opaline silica and glassy acid and intermediate volcanic rocks and,under propitious conditions,their changes which cause cracking and disruptive concrete expansions. In contrast to the widely accepted behaviour of proven deleterious components in aggregates,difficulties have arisen in interpreting test results and the variable performances in concrete of fine-grained quartzes in aggregate have caused much confusion. This confusion has been compounded from observations that some fine-grained quartzes exhibit undue reactivities according to rapid chemical and other severe small scale test results while these same aggregates in concrete structures have performed either satisfactorily or occasionally produced a few random pop-outs and possibly some minor cracking.

The behaviour of fine-grained quartz in aggregate represents a borderline material performance. Consequently it is necessary to show how such material could be assessed in order to eliminate the possibility on the one hand of incorporating deleterious aggregates in concrete and on the other hand of excluding suitable aggregates from use in concrete or in extreme cases condemning stone quarries and sand pits.

AGGREGATE CONSIDERATIONS

Aggregate consists essentially of an assemblage of various minerals which may occur as a mass of intergrown crystals or re-cemented particle fragments. Minerals which are commonly present include various silicates and alumino-silicates,carbonates and oxides such as quartz,haematite, limonite etc. Many of these minerals may be present in both fresh (unweathered) and in partly hydrated (weathered) forms. Except for some carbonates and fine-grained quartzes,which have suspect histories,these minerals are non-reactive in concrete. Aggregates which contain siliceous glass or secondarily deposited opaline silica are potentially reactive and may cause abnormal concrete expansions. Other known potentially reactive materials are not usually encountered in commercial aggregates.

Quartz may occur in a relatively inert macro-crystalline state or in one or both of the fine-grained forms namely, (a)micro-crystalline,when crystals are greater than 2 microns and (b)crypto-crystalline,when crystal sizes are less than 2 microns. While both fine-grained quartzes react very slowly with alkalis at moderately low atmospheric temperatures,the reaction rates of both,and more especially that of crypto-crystalline quartz,are significantly accelerated at elevated temperatures. For this reason the reaction potential of crypto-crystalline quartz,measured by the rapid chemical test and by the expansions of mortar bar specimens cured at elevated temperatures,tends to be over-emphasised. Several aggregates,which contained some crypto-crystalline quartz in their fine-grained component,have yielded variable,potentially reactive,chemical test results but in mortar specimens and in concrete the incidence of deleterious reaction has been negligible and abnormal expansions have not developed even after relatively long storage or field exposure times.

Amounts of fine-grained quartz vary in different aggregates and may even vary in aggregate taken from different positions in a quarry or sand deposit. Moreover the proportions of micro-crystalline and crypto-crystalline quartz comprising the total fine-grained quartz fraction are similarly variable and should be determined where necessary to permit a realistic interpretation and reconciliation of all the available chemical and mortar expansion test results.

The reaction rate of macro-crystalline quartz is limited by its small exposed surface,its dense structure and the relatively few defects or potential reaction sites in its lattice. On account of their decreasing crystal sizes and consequent increasing surface areas,the number of available reaction sites increases progressively in micro-crystalline and to a greater extent in crypto-crystalline quartz. At elevated temperatures the rates of reaction of both these fine-grained quartzes with alkalis increase significantly.

TESTS,TEST RESULTS and CONCRETE EXPANSION

The performance of aggregate in concrete is rather more complex than simple reactivity tests would suggest and consequently test results must be evaluated in accordance with the expected actions of several additional phenomena. In concrete,while the rate of reaction of alkalis and quartz constitutes the initial obligate variable,the rate of water absorption by the reaction product constitutes an independent, facultative variable which affects the swelling of reacting silica,its rate of change from the gel to the sol condition and ultimately the development of cracks and expansion of concrete. In addition concrete expansion may be affected by another independent variable namely,the amount and availability of void space which is present in the paste surrounding the reacting particle and in which swelling gel and sol can be accommodated. It should be pointed out that small amounts of reacting quartz are not sufficient to produce the stresses required to crack and expand concrete. Moreover,since quartz reacts relatively slowly,only small amounts of reaction product are available at any time to absorb the relatively large amount of free water which is usually present in concrete and hence this imbalance will accelerate the gel-sol transformation. This latter transformation limits the expansive action of reacting quartz and in turn limits the cracking and expansion of concrete. It is tentatively considered that the fine-grained quartz content of potentially deleterious aggregate is in the order 30-40% and that approximately 50% of this total should be crypto-crystalline.

Procedures which may be employed generally to determine the potential reactivity of aggregate are set out below:

(I) Petrographic examinations are necessary to determine the mineral content of aggregate together with additional tests to determine the contents of low refractive index minerals, low density minerals and fine-grained quartz.

(2) If large amounts of fine-grained quartz are identified, additional crystal size measurements and estimates of the crypto-crystalline quartz content are essential.

(3) The chemical test provides an early estimate of potential silica reactivity but it should be noted that its action is very severe and tends to overemphasise reactivity.

(4) Mortar expansion tests should be made on specimens stored, (a)at 20C which approximates to a moderate atmospheric temperature and,(b)at an elevated temperature(e.g.40-45C). It should be noted that storage at 20C gives reliable indications of the probable performance of aggregate in concrete but the time required for this test is very long; storage at an elevated temperature accelerates reactions and reduces the observation time but may promote anomalous reactions and expansions.

(5) Stereoscopic microscope examinations(at 40-I00x magnification)of the condition of aggregate and cement

paste in mortar specimens should be made at various ages. These examinations will indicate the onset of significant aggregate reaction as well as of cracks and other changes in the mortar specimens.

(6) Reasonable interpretations and evaluations of all the above data are most important. Although accelerated tests, made at elevated temperatures provide early indications of potential aggregate reactivity,expansion tests made at 20C and microscopical examinations yield the most significant evaluating information. It is essential that, to prove an aggregate is dangerous for use in concrete,all the test measurements,estimates and observations must be consistent in indicating undue aggregate reactivity and a capacity,due to the presence of sufficiently large amounts of reactive material,to cause deleterious changes in mortar and concrete exposed to moderate temperature conditions.

CONCLUSION

Although rapid tests have sometimes indicated undue aggregate reactivity and occasional small,slow developing mortar expansions caused by the presence of fine-grained quartz,the histories of concrete structures made with such aggregates do not invariably confirm the deteriorating effects portended by the test data. On occasions however,when aggregates contained large amounts of crypto-crystalline quartz,limited cracking and minor expansions have occurred in concrete structures. It is emphasised therefore that the determination of the crypto-crystalline quartz content of aggregate is essential to indicate potential deleterious reactivity in concrete and to permit fair assessments of all the test data.