Paper P11

Microstructural characteristics of some alkali-aggregate reactive granites of Peninsular Malaysia

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In Peninsular Malaysia, granite is the most important source of construction aggregates, accounted for over 75% of the total tonnage of aggregates produced. Granite aggregates is particularly important in the more developed regions of Selangor, Kuala Lumpur, Penang and Johor Bahru, where almost all aggregates are produced from granitic rocks.

Granite aggregates are the preferred material used in concrete in Peninsular Malaysia. They are generally considered as non alkali-aggregate reactive (Chow & Abdul Majid Sahat, 1990; Yeap, 1992). Alkali-aggregate reaction (AAR) is a chemical reaction where alkali cations in solution (Na^+, K^+) react with reactive aggregates in the concrete. Through this reaction, amorphous phases are formed, which imbibes water and swells. It causes expansion, cracking and weakening of the concrete structure and potentially leading to a collapse.

There are three types of AAR, which are associated with the type of alkali-reactive aggregates. Alkali-silica reaction (ASR), which was identifie firs by Staton (1940) and Staton *et al*. (1942), involves the reaction of disordered forms of silica minerals in aggregates (Hobbs, 1990). Reactive silica aggregates are opal, chalcedony, volcanic glass, cristobalite, tridymite as well as cryptocrystalline, microcrystalline and strained quartz. Alkali-phyllosilicate reaction is believed to be due to the occurrence of swelling phyllosilicate minerals (Gillott *et al*., 1973; Gillott, 1975). Alkali-carbonate reaction (ACR) which has been reported with some dolomitic limestones and carbonates with siliceous or argillaceous components (Swenson & Gillott, 1960; López-Buendía *et al*., 2006) will not be considered in this paper.

Alkali reactive minerals can occur naturally in granite aggregates in several ways. Primary minerals of the granite and associated rocks found in the quarries are generally devoid of reactive minerals, although minor microcrystalline quartz are present in mymerkite in some granites and as individual grains in some fine-graine microgranite and aplite. Granites near the contact with the country rocks often have metasedimentary enclaves, which contain phyllosilicates and microcrystalline quartz. However, in general these enclaves only constitute a very small proportion of the rock material. Granitic rocks can contain reactive secondary minerals such as opal and chalcedony which infil discontinuities. Field studies of granite quarries show that such mineral veins are rare in Peninsular Malaysia. Chalcedony has been observed in only one quarry and it has also reported in Selangor by Yeap (1992). Faulting has generated a diverse variety of deformed granites and caused severe straining and grain size reduction of the quartz grains in the granite (Ng, 1994). The effect of fault deformation on ASR of granites in Peninsular Malaysia has been discussed by Ng & Yeap (2007), and elsewhere (e.g. Kerrick & Hooton, 1992; Wigum, 1995). Lastly, reactive secondary minerals can also form as a result of mineralisation and alteration of granites.

Tests available for the detection of potentially reactive aggregates have been reviewed by Wigum *et al*. (1997). Petrographic examination is a useful and fast method for the identificatio of potentially deleterious minerals in the aggregates, while the accelerated mortar bar expansion test (ASTM C1260-94) measures the expansion of three mortar bars in immersed in 1N NaOH at 80 °C. Average expansions of more than 0.20% at 16 days after casting are indicative of potentially deleterious expansion, while expansions between 0.10% and 0.20% have marginal behaviour. According to Oberholster & Davies (1986), samples with expansion greater than 0.11% at 12 days is considered as deleterious.

In this study, more than 150 samples of granite and associated rocks were collected from quarries and rock slopes. Thin sections were prepared for petrographic examination. After the petrographic examination, sixteen representative samples collected from granite quarries were subjected to expansion test. Two samples are typical granite that are not deformed and has minimal alteration (sericitisation of plagioclase and chloritisation of biotite). The other twelve samples contain potentially deleterious minerals, all of which experienced marginal to deleterious expansion in the test (0.1% - 0.28%). This study will concentrate on the petrographic microstructures of these alkali-aggregate reactive granites.

Of all the minerals identifie in this study, chalcedony is considered as most reactive. Chalcedony infill irregular spaces in the cataclastic granite collected from a quarry in central Selangor. The chalcedony has fibrou habit and forms radiating masses of about 100 μm in diameter, between secondary pyrite and mica grains.

Faulting has resulted in the formation of a wide variety of fault rocks in the granite, ranging from fault gouge and breccias, to cataclasites and mylonites (Ng, 1994). Being incohesive, fault gouge and breccias seldom end up in the production of aggregates. Strained quartz and microcrystalline quartz are the main potentially deleterious mineral in cataclastic and mylonitic granites. Quartz with undulatory extinction is omnipresent in all undeformed and deformed granite samples. However, not all quartz with undulatory extinction is indicative of deleterious behaviour (West, 1991). It is generally accepted that quartz with undulatory extinction angle larger than 15°, and quartz with deformation bands and lamellae is considered as strained quartz. All quartz clasts in the cataclastic granites are strained, while in the mylonites, relict quartz clasts, which often form ribbon texture also show large undulatory extinction angle, and less frequently, deformation bands and lamellae.

With progressive deformation quartz clasts in the mylonites are polygonised and recrystallised. The formation of polygonal subgrains often progresses inwards from the clast boundaries. The subgrains are equidimensional to weakly elongated, the latter are aligned parallel to the mylonitic foliation. The subgrains are mainly 20 μm to 30 μm in diameter.

Deformation of granites results in grain size reduction. Microcrystalline (<60 μm) quartz occurs in cataclastic and mylonitic granites. In the cataclasites, microcrystalline quartz is produced by abrasive wear, and it is consisting of angular quartz clasts in

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the matrix. In the mylonites, the microcrystalline quartz is consisting of quartz subgrains and neoblasts, formed as a result of recovery of highly strained quartz. The neoblasts are formed by subgrain rotation mechanism and have similar shape and size as the subgrains. The microcrystalline quartz is often concentrated in quartz-rich bands that form the fabric element of the mylonite.

Microcrystalline quartz is also found in silicifie cataclastic granites, which also experienced minor chloritisation and sericitisation. The silicifie cataclastic granites contain abundant secondary quartz in the matrix and the quartz also forms veinlets. Although, quartz can occupy up to 75% of the silicifie rocks, generally the microcrystalline fraction is only about 25%.

Microcrystalline quartz is also found in strongly sericitised granite, where all the plagioclase has been completely altered to sericite. In some of the sericitised plagioclase, very fin irregularly-shaped quartz grains are observed, probably precipitate from the excess silica produced during the alteration process. One sericitised granite sample shows the largest expansion (0.28%) in the mortar bar test. Due to the high sericite content (~35%), it is unclear whether the expansion is caused by ASR or alkali-phyllosilicate reaction or both.

The microstructural characteristic of some alkali-aggregate reactive granite has been described. Granitic rocks having similar characteristics are potentially alkali reactive and should be verifie by accelerated mortar bar test. Although, alkali reactive rocks are present in some quarries in Peninsular Malaysia, generally these rocks will not pose serious problems in the production of concrete aggregates as they constitute only a small proportion of the extracted rocks.

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