Geol. Soc. Malaysia, Bulletin 26, April 1990; pp. 97 - 108

Potential alkali-silica reactivity of tuffaceous rocks in the Pengerang area, Johor

CHOW WENG SUM AND ABDUL MAJID SAHAT

Geological Survey of Malaysia
Ipoh

Abstract : Concrete is known to deteriorate as a result of interaction between certain reactive minerals in some types of aggregates and the alkaline pore fluids originating from Portland cement. This interaction which is known as alkali-silica reaction (ASR), was highlighted in Malaysia in March 1988 when the Singapore Government banned the import of volcanic quarry stones from the Pengerang area in Johor.

Based on rock aggregate tests, the mechanical and physical properties of tuffaceous rocks are within the acceptable limits as recommended by JKR Malaysia for use as constructional aggregates. However, chemical tests on potential alkali-silica reactivity showed that the tuffs from Pengerang contained reactive minerals. X-Ray Diffraction studies showed the possible occurrences of reactive tridymite and cristobalite in some of the samples. Petrographic studies showed that other reactive minerals are chalcedony and strained quartz, and also possibly, the crypto- to microcrystalline quartz which from the groundmass of the tuffs.

However, as for granites, which are innocuous and abundant in Peninsular Malaysia, the problem of alkali-silica reactivity should not be too worrying.

Abstrak : Konkrit telah diketahui boleh menjadi retak akibat tindakbalas antara mineral silika tertentu yang reaktif yang terdapat simen. Tindakbalas ini dikenali sebagai tindakbalas alkali-silika (ASR) yang telah menjadi tumpuan di Malaysia apabila kerajaan Singapura mengharamkan impot aggregat batuan tuff dari kawasan Pengerang di Johor pada bulan Mac 1988.

Berdasarkan dari ujian aggregat batuan, sifat-sifat mekanik dan fizika batuan berkenaan masih dalam lengkungan piawai seperti yang ditetapkan JKR Malaysia untuk aggregat pembinaan. Walau bagaimanapun, ujian kimia untuk potensi tindakbalas alkali-silika (ASR) terhadap batuan tuff dari Pengerang menunjukkan yang batuan berkenaan mengandungi mineral-mineral yang reaktif. Hasil dari analisis belauan sinar-X yang dijalankan, sebahagian dari sampel menunjukkan kemungkinan kehadiran mineral reaktif seperti tridimit. Kajian petrografi menunjukkan kehadiran mineral-mineral reaktif seperti kalsidoni, kuarza yang tericih dan mineral jisim latar yang terdiri dari kripto-kemikrohablur kuarza.

Oleh kerana batuan granit banyak terdapat di Semenanjung Malaysia, mengelakan dari menggunakan aggregat yang mempunyai ASR bukanlah satu masaalah yang besar.

INTRODUCTION

Concrete is known to deteriorate as a result of interaction between certain reactive minerals in some types of aggregates, and the alkaline pore fluids

Presented at GSM Annual Geological Conference '89

originating from Portland cement. This interaction which is known as alkali-silica reaction (ASR) can result in cracks in concrete beams and columns.

Alkali-silica reactivity of aggregates was first identified in the USA in 1940 and since then, tremendous advances had been made in this field of research.

The problem of ASR was highlighted in Malaysia in March 1988 when the Singapore Government banned the import of volcanic rocks from the Pengerang area in Johor for use as concrete aggregates as they supposedly possessed ASR properties. It is prudent to stress here that in Malaysia, to-date, there is yet to have a single reported case of structural failure in buildings or other civil structures resulting from ASR. However, volcanic rocks have actually been utilised for construction purposes in certain parts of Malaysia and such a threat from ASR cannot be ignored altogether.

CHEMISTRY OF ALKALI-SILICA REACTION

Alkali-silica reaction occurs when there is interaction between the alkaline pore fluid (principally orginating from Portland cement) and certain siliceous minerals in some aggregates, forming a calcium-alkali-silicate gel. This gel readily absorbs water, producing a volume expansion which induces an expansive force resulting in cracks in concrete.

The reactivity of the different siliceous minerals depends on the amount of order in the crystal structure. Opal, which has a very disordered structure, is the most reactive form of silica. Other forms of silica like glasses,microcrystalline and cryptocrystalline quartz, strained quartz, chalcedony, tridymite and cristobalite are of intermediate activity.

LOCATION OF STUDY AREA

The Pengerang area is located at the southeastern tip of Peninsular Malaysia (see Fig. 1) and except for its northern margin, is surrounded by water, with the South China Sea to the east, the Straits of Singapore to the south and the Johor Straits to the west.

TOPOGRAPHY AND DRAINAGE

The area is low-lying to undulating, with only a few hills exceeding 200 ft (61 m). The highest hills in the area are Bukit Pelali and Bukit Pengerang which rise to 627 ft (191 m) and 611 ft (186 m) respectively (see Fig. 2).

Drainage in the area is poor, consisting of only a few small streams which drain into broad mangrove-choked estuaries.

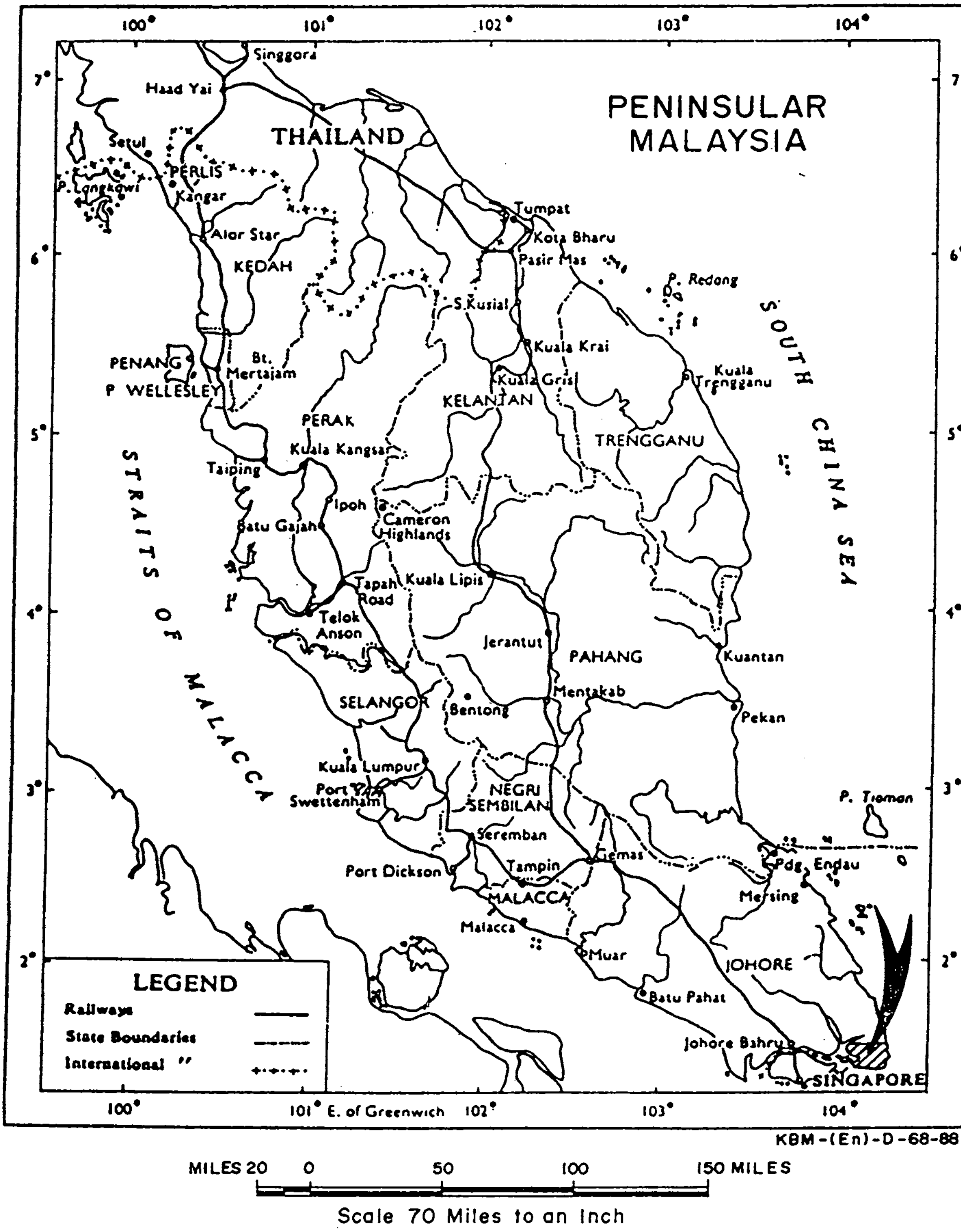

Figure 1 : Location of the Pengerang area, Johor

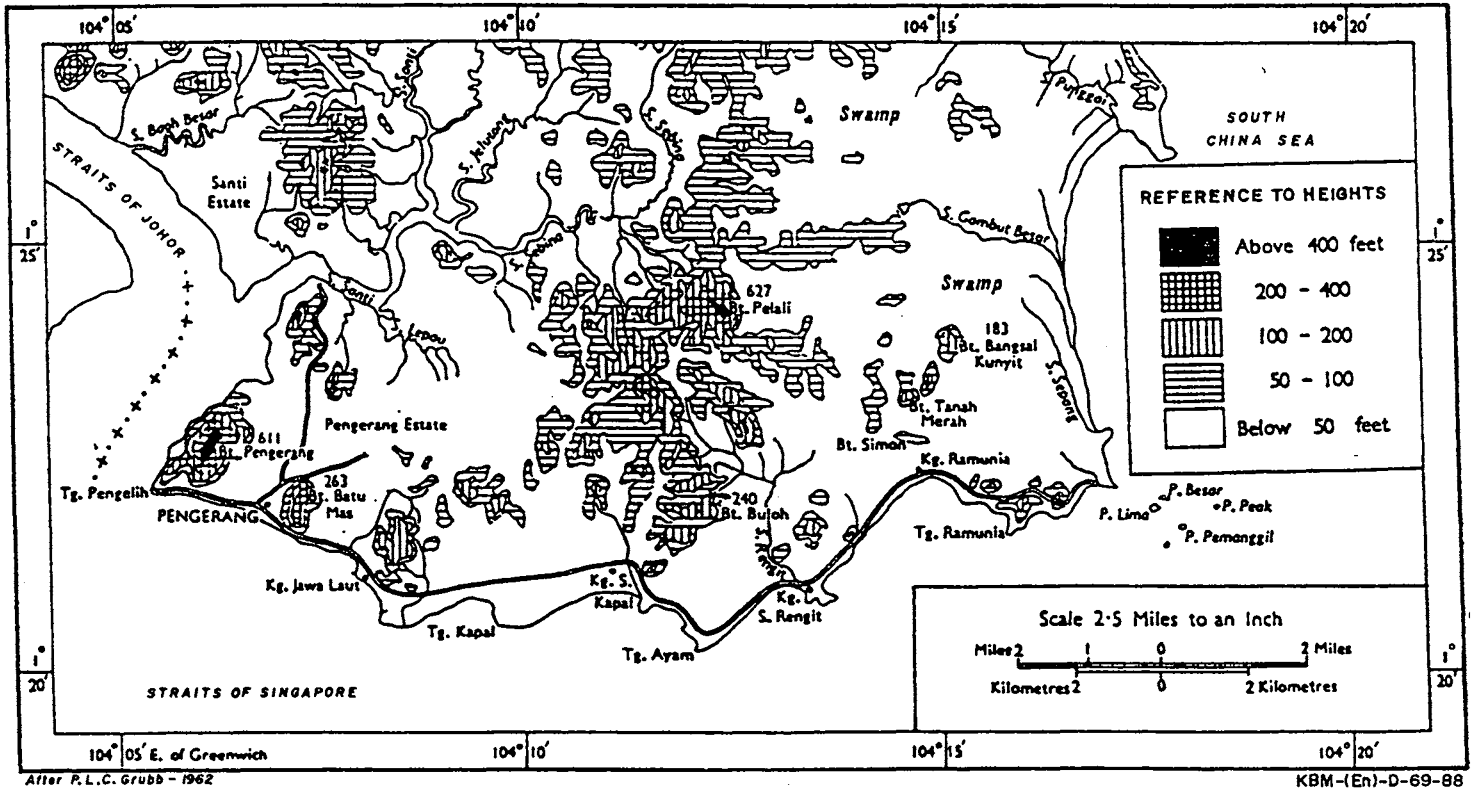

Figure 2 : Topographical map of the Pengerang area, Johor

GEOLOGY OF THE AREA

The Pengerang area had been mapped by Grubb in 1968 and Pre-Carboniferous (?) metamorphic rocks comprising graphitic muscovite-quartz schists were found to form a broad belt trending approximately parallel to the coastline near Tanjong Punggai in the northeast corner (see Fig. 3).

Following this, a thick succession of Triassic(?) to Carboniferous (?) volcanic rocks comprising rhyolitic flows, ashy tuffs and agglomeratic tuffs occupy the central to western portions of the area. Tuff are particularly prevalent, forming the more resistant undulating topographical highs and hills. As most of the hills in the area are underlain by tuffs, it is not surprising that almost all the quarries in the area produce tuffaceous rock aggregates.

Subsequent to this, the volcanic rocks were intruded by granite in the form of five small plutons, possibly in late Mesozoic. During the final stages of igneous activity, a mild phase of dyke and sill intrusion took place.

Recent deposits consisting of swamp clays and marine sand are widespread, covering the lowlands of the Pengerang area.

METHOD OF INVESTIGATION

Twelve samples of tuffaceous rocks were collected, of which eight, (Samples Nos 1 to 7 and No.9) were from Locality A and the remaining four, (Sample Nos 10, 11, 12, 14) from Locality B (see Fig. 3). The rocks were tested chemically for potential alkali-silica reactivity following ASTM C 289-81. Petrographic and X-ray Diffraction studies were also carried out to identify the type of reactive silica, if present.

RESULTS OF INVESTIGATION

Potential Alkali-Silica Reactivity

Other than the twelve samples from Localities A and B, one other sample No. MP1, which was a granite, was collected from the Pulai area in Johor and used as a control.

The results showed that other than sample No. MP1, all other samples showed a low reduction in alkalinity and a moderate to high increase in dissolved silica (see Table 1).

When the results were plotted on a standard graph (see Fig. 4) all twelve tuffaceous samples were found to be deleterious as compared to the single granite sample which was innocuous.

Table 1 : Results of chemical tests for potential alkali-silica reactivity [following ASTM (289-81)]

Sample No.	Reduction in alkalinity Rc (millimoles/litre)	Dissolved silica Sc (millimoles/litre)
1	12.8	52.0
2	16.6	46.0
3	5.1	66.0
4	5.1	65.0
5	10.2	52.0
6	17.9	54.0
7	20.4	58.0
9	17.9	64.0
10	14.0	96.0
11	19.0	52.0
12	16.6	96.0
14	15.3	67.0
MP1	5.1	30.0

Tests carried out by Geochemistry Division, Geological Survey of Malaysia

X-Ray Diffraction Studies

X-Ray Diffraction studies were carried out on all twelve tuffaceous samples by the Mineralogy and Petrology Section Geological Survey of Malaysia. Results showed that the minerals detected were mainly – quartz and feldspars and serpentine. However, some samples showed the possible occurrences of reactive tridymite.

Petrographic Study

Locality A

The rocks from Locality A ware mostly crystal lithic tuff with small amounts of crystal tuff. Sericite, crypto- to microcrystalline quartz, plagioclase, some orthoclase and muscovite form the groundmass. Larger crystals of quartz and plagioclase are present as phenocrysts and in most thin sections, lithic fragments are found. Calcite commonly replaces parts of the groundmass and some of the plagioclase phenocrysts and lithic fragments. Small rounded spheroids of chalcedony are commonly present in most of the rock samples.

Locality B

Rocks from Locality B are crystal tuff although a small amount of lithic fragments are found in some of the rocks. Thin section studies showed that sericite, crypto- to microcrystalline quartz, and some plagioclase and orthoclase form the groundmass. Larger crystals of quartz and plagioclase are present as phenocrysts. Some of the quartz in the groundmass and phenocrysts appeared to be strained as a wavy extinction was observed. A trace amount of chalcedony was found in one of the thin sections.

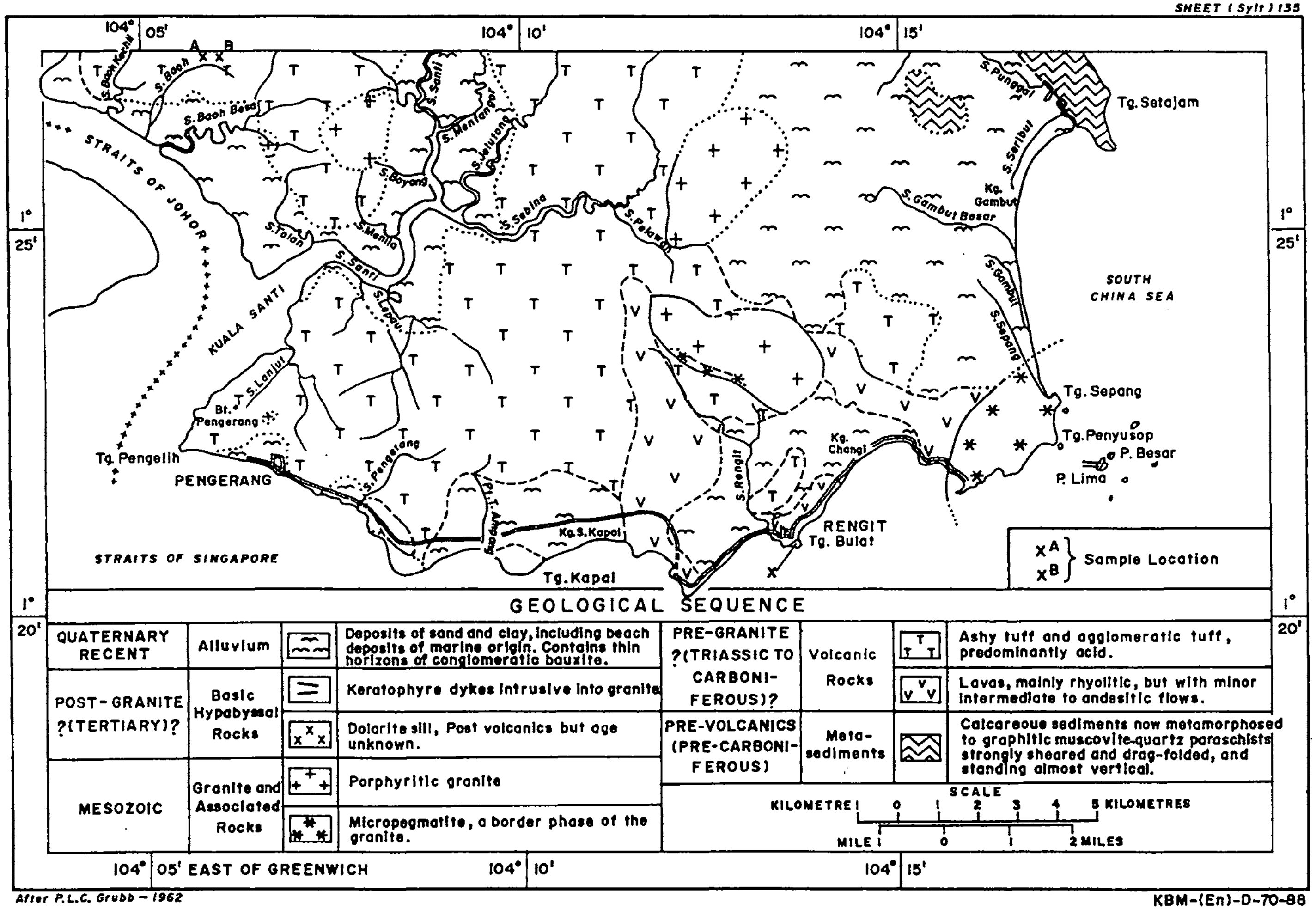

Figure 3 : Geology of the Pengerang area, Johor

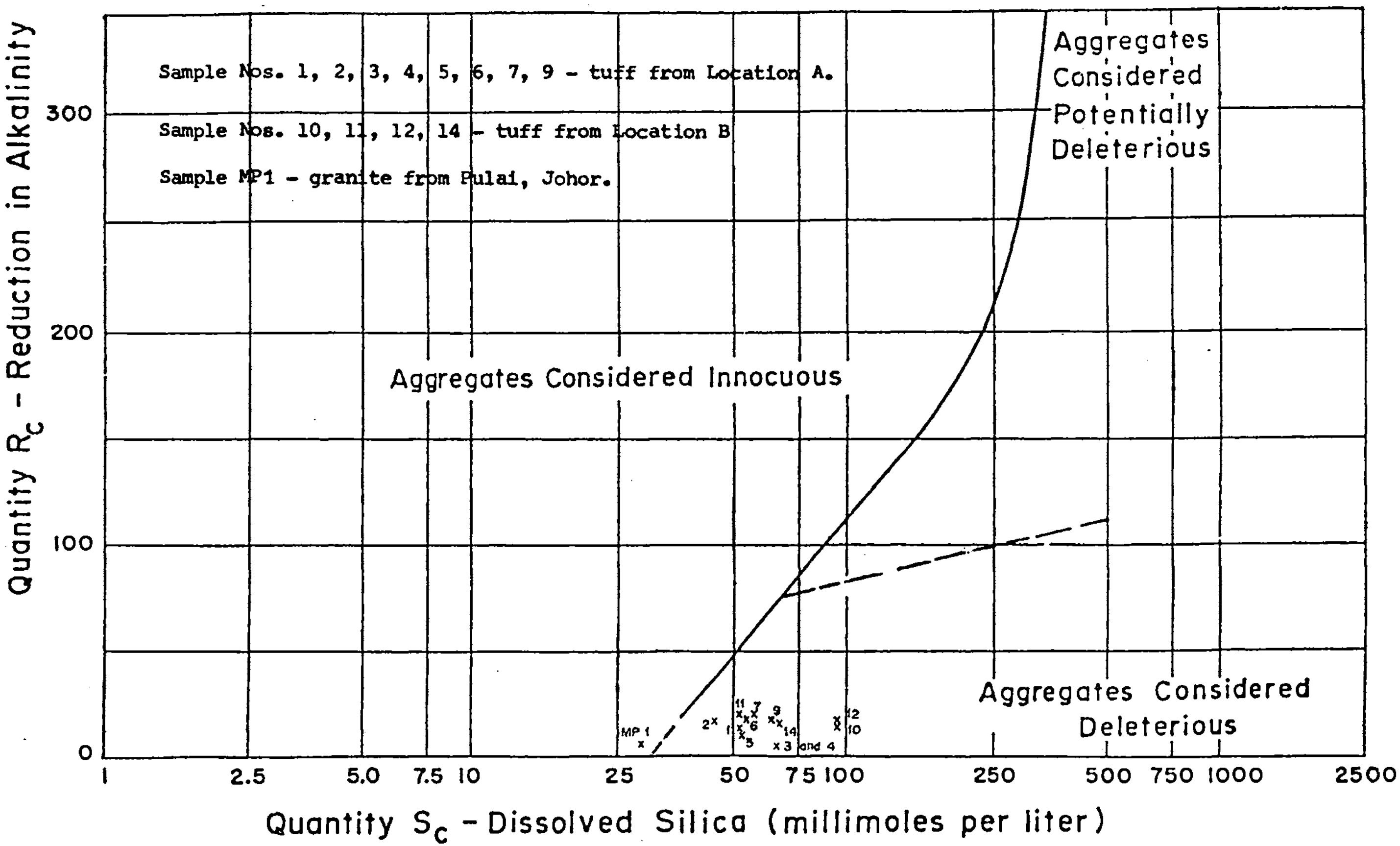

Illustration of Division Between Innocuous and Deleterious Aggregates on Basis of Reduction in Alkalinity Test.

Figure 4 : Results of potential alkali-silica reactivity

ROCK AGGREGATE TESTING

The tuffs from the Pengerang area were not subjected to rock aggregate testing for their mechanical and physical properties as the amount of samples collected were insufficient.

However, rock aggregate tests had been conducted by the Geotechnical Laboratory of the Engineering Geology Section, Geological Survey of Malaysia on tuffs from Bukit Beryl in Terengganu, Bukit Musoh in Pahang Tenggara, Bersia in Grik, Perak, and the Genting Highland area in Selangor.

The results (see Table 2) showed that the mechanical properties (i.e. Impact Value, Crushing Value, 10% Fines Value and Los Angeles Abrasion Value) of the tuffs are within the acceptable limits as recommended by Jabatan Kerja Raya (JKR) Malaysia (see Table 3) for use as road pavement, airfield pavement and concrete. As for the physical properties, the Water Absorption and Soundness Values of the tuffs are well within the acceptable limits. However, the Flakiness Indices of the tuffs, except for the sample from Genting Highland, are above the acceptable limits for airfield pavement and concrete. This should not be a deterrent as the Flakiness Index of a rock could be improved by altering the crushing methods.

It is expected that tuffs from the Pengerang area would have similar mechanical and physical properties with those from Bukit Beryl, Bukit Musoh, Bersia and Genting Highland.

DISCUSSION

It has been the practice in Malaysia to conduct rock aggregate tests on quarry stones to determine their suitablility for constructional purposes. Based solely on rock aggregate test results, tuffs would definately be suitable for all constructional purposes as their mechanical strength and physical properties are comparable to that of granites and are within the acceptable limits as set by JKR.

However, chemical tests conducted on tuffs from Pengerang showed that the rocks would have an alkali-silica reaction (ASR) with Portland cement which is deleterious to concrete.

The reactivity of the tuffs is due to the presence of chalcedony and strained quartz and possibly, the crypto- to microcrystalline quartz groundmass of the tuffs. Tridymite which are possibly present in the tuffs could be the reactive minerals as well. The reactive minerals would react with the alkaline pore fluids from the cement to form a gel which would readily absorb water and expand in volume. The expansive force would lead to cracks in concrete.

Damage from alkali-silica reactivity can occur only when the concrete is constantly or intermittently exposed to moisture such as rain, groundwater, seawater, heavy condensation or relatively high humidity. As such, alkali-silica

Table 2 : Results of Rock Aggregate Tests conducted on some tuffs

Locality	Sample	Physical Propeties				Mechanical Properties			
		S.G	Flakiness Index %	Water Absorption %	Soundness Values %	Impact Values %	Crushing Values %	10% Fines Values T.F.	Los Angeles Abrasion Values %
Bukit Musoh Pahang Tenggara	Siliceous Tuff	2.65	36.7	1.6	3.2	22.0	18.1	18.5	23.0
Bukit Musoh Pahang Tenggara	Tuff	2.67	35.7	1.5	4.9	14.6	10.9	32.0	14.0
Bukit Beryl Terengganu	Greenish Tuff	2.59	44.1	0.7	0.3	18.2	16.2	27.5	13.0
Bukit Beryl Terengganu	Blackish Tuff	2.68	36.1	0.2	0.1	17.1	15.7	27.7	15.0
Bersia, Grik, Perak	Tuff	2.66	48.5	0.9	4.6	31.2	22.9	15.2	18.6
7th Mile, Genting Highland Selangor	Crystal Tuff	2.66	48.5	0.9	4.6	31.2	22.9	15.2	18.6

Tests carried out by the Geotechnical Laboratory, Engineering Geology Section, Geological Survey of Malaysia

Table 3 : Acceptable Limits as recommended by JKR, Malaysia.

Property	Usage					
	Road Pavement		Airfield Pavement		Concrete	
	Surfacing	Crushed Stone Base	Surfacing	Crushed Stone Base	Pavement	Structural
Water Absorption	–	–	2% max.	–	–	–
Flakiness Index	–	–	30% max.	–	30% max.	35% max.
Soundness Value Sodium Sulphate Test	12% max.	20% max.	12% max	20% max.	12% max.	12% max.
Impact Value	–	–	–	–	30% max	45% max
10% Fines Value	–	–	–	–	10 Tons min.	5 Tons min.
Crushing Value	–	–	30% max.	30% max.	35% max.	
Abrasion Value	40% max.	50% max.	–	–	–	50% max.

After Ting W.H. & Chew S.H. (1987)
JKR Headquarters.

reactivity of tuffs in concrete can still be controlled if the concrete is kept dry. Alternatively, the alkali level of the cement is kept low by either (a) using a Portland cement with low alkali level or (b) substitute sufficient of the Portland cement with pulverised fuel ash or ground granulated blast-furnace slag.

CONCLUSION

Tuffs from the Pengerang area in Johor do have an alkali-silica reaction (ASR) with cement which is deleterious to concrete. The reaction is due to the presence of reactive minerals like chalcedony and strained quartz, and possibly, crypto- to microcrystalline quartz and tridymite within the tuffs which react with the alkaline pore fluids from Portland cement to form a gel. The gel readily absorbs water and expands in volume and the expansive force could lead to cracks in concrete.

As granitic rocks which are innocuous to alkali-silica reaction are easily available in Peninsular Malaysia, the problem of only having to utilise tuffs which have an alkali-silica reactivity for constructional purposes does not arise.

REFERENCES

BUILDING RESEARCH ESTABLISHMENT DIGEST 330, 1987. Building Research Station, Garston, Watford.

GRUBB, P.L.C., 1968. Geology and Bauxite Deposits of the Pengerang area, Southeast Johore. Geological Survey West Malaysia District Memoir 14.

MORINO, K., 1984. The Petrological Study of Alkali-Reactive Aggretate. Transactions of the Japan Concrete Institute Vol. 6, 1984.

TING, W.H. AND CHEW, S.H., 1987. Investigation and Evaluation of some crushed rock aggregate found in West Malaysia. Unpubl. rept. JKR Headquarters.

Manuscript received 25 April 1989