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.

Evaluation of Quartzite and Granite Aggregates Containing Strained Quartz

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ABSTRACT

Results of optical microscopy, mortar bar expansion tests at 38 and 60 C and rapid chemical tests on quartzitic and granitic aggregates containing strained quartz are summarised. Limits are suggested for acceptable expansion in mortar bar tests at 60 C regime and the percentage of quartz showing strain effect and angle of undulatory extinction.

INTRODUCTION

For a number of concrete dams to be constructed in India, attention is being paid to the effects of strained quartz on evaluating concrete aggregates. As a result, a large volume of data on quartzite and granite aggregates from different sources has become available. Results of their evaluation using optical microscopy, mortar bar expansion tests at 38 and 60 C regimes and rapid chemical tests are presented in this paper.

DESCRIPTION OF AGGREGATES

Summary of petrographic details in respect of the aggregates is shown in Table 1. The strain effect in quartz grains was measured in terms of undulose extinction(UE) angle (Dolar Mantuani,1983). Figure 1 shows the presence of strained quartz in a quartzite aggregate. Granitic aggregates contained lesser (40-45 percent) quartz, accompanied by considerable amount of alkali felspars altered to clay minerals or sericite (Fig 2). No metastable silica minerals were detected.

DISCUSSION OF TEST RESULTS

The aggregates were subjected to the rapid chemical test (ASTM C289) for 24 hours, 3 days and 7 days and to mortar bar expansion tests with four ordinary portland cements having alkali contents (Na_2O equivalent) of 0.25, 0.57, 0.89 and 1.0 percent at 38 and 60 C. Unless mentioned otherwise, the results and conclusions pertain to expansion with high alkali (1%) cement at 60 C. In addition to procedure of ASTM C227, in a few tests, mortar bars were made using five pebbles embedded in standard sand, as per Buck (1983).

TABLE-1
DESCRIPTION OF AGGREGATES

Sl No	Type	Quartz grain size, 'mm'	Strain effect UE°	Strain effect %	Modal Composition %					
1	Quartzite	0.025-0.12	31-40*	90	Qz	Ir**	Bio	Chl		
		<0.025	20-30*	90	94	1	2	3		
2	Quartzite	0.075-0.575	32-40*	90	91	2	2	3		
		<0.075	22-33*	90						
3	Quartzite	0.040-0.0525	33-39*	90	93	2	2	3		
		<0.0125	23-28*	92						
4	Quartzite	0.030-0.125	31-42*	85	89	3	8	-		
		0.005-0.030	21-28*	90						
5	Quartzite	0.025-1.375	33-35	25	79	2	5	2		
							(12 mica)			
6	Quartzite	0.1 - 0.3	30-40	65	78	7	5	10		
7	Quartzite	1.0 - 3.0	25-40	70	88	4	8	ND		
					Qz	Fels	GM	Ir		
8	Greywacke	0.025-0.40	15-20	25	50	7	40	3		
9	Ortho-quartzite	0.2 - 1.5	15-20	75	94					
					Aug	Fels	Ir	Br	Qz	Bio
10	Dolerite	0.175-1.0	22-28	15	44	26	14	10	4	2
					Qz	Or	Pl	M	Bio	Ac
11	Granite	0.006-1.5	11-15	15	40	12	6	30	7	5
12	Biotite-Granite	0.075-1.25	30-40*	75	45	31	8	-	12	4
		<0.075	23-28*	23						
13	Biotite-Gneiss	0.050-0.550	25-30	20	40	22	13	9	14	2
14	Augen-Gneiss	0.050-0.625	26-32	30	42	28	11	5	9	5
15	Granite-Gneiss	0.1 - 0.8	20-25	50	40	37	9	-	8	6
16	Phyllite	Very fine grained	20-25	70	37	26	-	-	13	24
17	Sand	-	30-45	80	70	5	-	2	7	16

*Denotes two generations of quartz
**Abbreviations: Qz- quartz, Ir- oron oxide minerals, Bio- biotite, Chl- chlorite, Fels-feldspar, GM-ground mass Aug-augite, Or-orthoclase, Pl-plagioclase, M-muscovite, Ac-accessory minerals

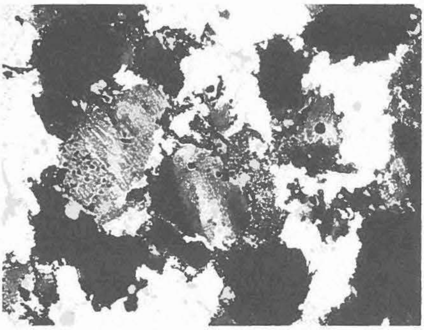

Fig 1 Presence of strained quartz in quartzite

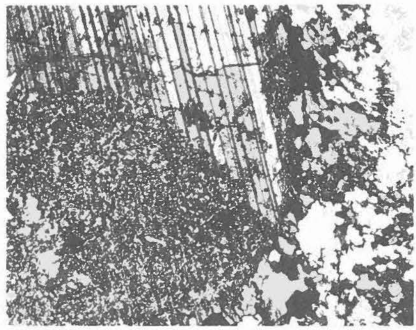

Fig 2 Alteration of alkali felspars to clay minerals

For quantifying the effect of strained quartz, four parameters namely the UE angle, grain size, percentage quartz showing strain effect and the proportion of quartz in the modal composition are important. Amongst these, the grain size did not show any clear trend with the expansion. For any one type of aggregate and cement combination, expansion increased with the proportion of quartz grains showing strain effect (Fig 3) and the UE angle (Fig 4).

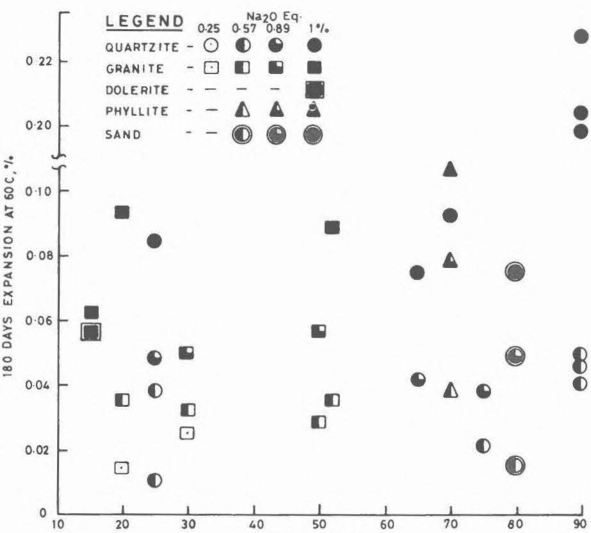

Fig 3 Percentage strained quartz v expansion with different cements

Using the aggregates crushed to sand sizes (as per ASTM) or five pebble-size pieces, the expansions were of similar magnitude. Using aggregates in a crushed form has the advantage that they can be used both for 38 and 60 C regimes as the test at 38 C is presently standarised for sand grading. It was thus preferred to evaluate aggregates after crushing to sand sizes.

The rapid chemical tests carried out for the specified 24 hours indicated all these aggregates to be innocuous'. However, when the exposure was prolonged to 7 days, the quartzitic aggregates were shown to be reactive' (Fig 5).

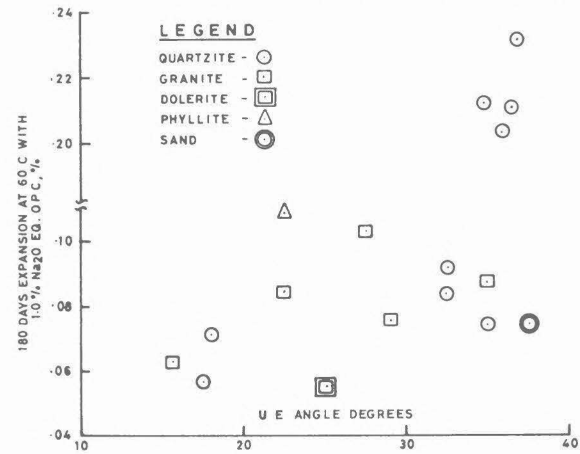

Fig 4 Average UE angle v expansion

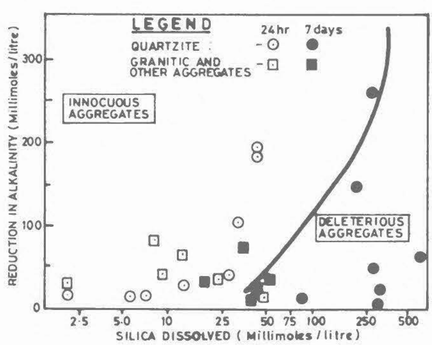

Fig 5 Results of rapid chemical tests

In the mortar bar test at 38 C, the maximum expansions with 1 percent alkali cement were generally less than 0.05 percent after 180 days; only aggregates 1 and 4 (Table 1) exceeded the existing ASTM C33 limits at 3 and 6 months. Contrasted to that mortar bars made with these aggregates run at 60 C exceeded the threshold values suggested by Buck

(1983) by wide margins; sometimes even with low-alkali cements. A need, therefore, was felt for setting realistic threshold for mortar bars made with high alkali cement and stored at 60 C.

RECOMMENDATIONS

Expansion of Mortar bars with low alkali cement seldom exceeded 0.05 percent after 180 days (Fig. 3). For aggregates showing uniform extinction, Gogte (1973) had observed linear expansions after six months at 50 C of 0.016 to 0.058 percent. From these considerations, an expansion of the order of 0.04 percent with high alkali cements at six months can certainly be considered as the lower bound. On the other hand, granitic aggregates similar to those reported here have shown distress due to ASR in service as reported elsewhere in this Conference; the expansions at 180 days in case of such aggregates were generally of the order of 0.06 percent and higher. The broken surfaces of mortar bars in these cases generally showed presence of typical alkali silica gel (Fig 6). Considering all these points, it is suggested that for mortar bar tests made with high alkali (1%) cement at 60 C, expansion of the order of 0.05 percent at 90 days or 0.06 percent at 180 days be taken as indicative of reactive aggregates. For quartzite aggregates, a minimum of 25 percent quartz showing strain with UE angles of 25° and above may indicate potential reactivity. For granitic aggregates, however, similar expansions were observed with only 15 percent quartz showing strain effects (Fig 3) and the limit has to be proportionately lower. The role of alkali felspars (Visvesvaraya et al 1986) should also be taken into account.

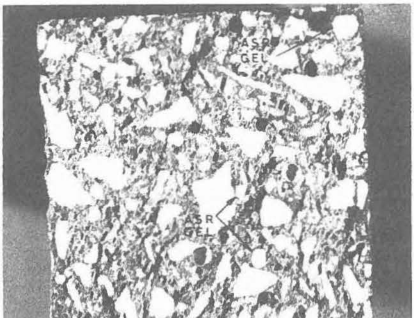

Fig 6 ASR gel in pores of broken mortar - bar

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