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Effect of Grain Size and Reaction Time in Characterisation of Aggregates for Alkali Silica Reaction Using Chemical Method

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ABSTRACT
Concrete can deteriorate as a result of alkali aggregate reaction, an interaction between alkalis present in alkaline pore solution originating from the Portland cement and reactive minerals in certain types of aggregates. Potential reactivity of aggregates with regard to alkalis present in concrete mix can be determined by Mortar Bar method, Chemical Method and Petrographic analysis. Of these the chemical method though is quick and does not require a large quantity of material for testing yet have its own inherent limitations. It does not ensure completion of reaction as the observations are limited to 24hour only and also does not assess the effect of varying the combination of coarse and fine aggregates. A study on chemical method by allowing the reaction for a prolonged time up to 96 hours and also on different grain size ranged matrix was carried at Central Soil and Materials Research Station, New Delhi. Simultaneously the test results of the modified method are compared to the existing Mortar Bar method, Chemical Method and Petrographic analysis The outcome of the studies clearly reflects that the grain size play an important role in the reaction, the reaction time has a demarked impact on reactivity, in the cases having a high value of silica release the choice of reduction in alkalinity as an indicator of degree of reaction is not reliable, instead measuring remaining Na_2O concentration in Sodium hydroxide solution after the reaction seems to be much more meaningful in justifying the silica release.
Keywords: Aggregate, Petrographic, Mortar Bar Expansion, Alkali, Silica,

I. INTRODUCTION

Alkali aggregate reaction (AAR) occurs when there is interaction between the alkalis present in the pore solution and silicious minerals in some aggregates forming a calcium alkali silicate gel(1). Potential reactivity of aggregates with regard to alkalis present in concrete mix can be determined by chemical method (CM) developed by Milenz and co-workers of US Bureau of Reclamation (USBR) in USA(2,3,4). For determining potential reactivity of aggregates CM - ASTM C 289 -81 and IS 2386 (Pt VII) (5, 6) are being followed. These methods cover the chemical determination of the potential reactivity of an aggregate with alkalis in a Portland cement concrete as indicated by the amount of reaction during 24 hours at 80°C between 1N NaOH solution and aggregate that has been crushed and sieved to pass a 300µm sieve and retained on a 150µm sieve. This chemical method has had a word wide success, because it is quick, easy to do and does not require a large quantity of material. However, it suffers from several defects like

Non Representative Grain Size of Sample (150µm to 300µm)

The material passing the 150µm sieve is discarded. The desired fraction is washed. The reactive silica present in amorphous state in the aggregates passes with the fraction smaller than 150µm. Washing of the desired fraction removes any traces of amorphous silica.

Abnormality in Measurement of Reduction in Alkalinity (Rc)

The Reduction in Alkalinity is the measurement of remaining OH^- ions concentration after the reaction. The choice of measuring OH ion concentration is not correct as it is involved in two reactions. Apart from OH^- ion the HCl titration using phenolphthalein indicator, is also influenced by some other anions such as carbonates, silicates, chlorides and sulphates.

Inadequate Reaction Time

Strained quartz is a slow reacting material, thus the reaction time of 24 hours is not adequate to ensure release of total silica content.

Anomaly in Estimation of Nature of Aggregate in Siliceous Limestone Samples

Siliceous limestone does not show deleterious nature because of low silica content compared to the very high $CaCO_3$ level and a very high Rc because of carbonates.

Reappraisal of Chemical Method (Sorentino's Kinetic Test Method)

Sorrentino el al[7], reappraised the CM by considering

- Grain size of materials (60% of 150µm to 300µm and 40% passing 150µm),
- Extension of reaction time upto 96 hrs. and
- Reduction in alkalinity

Considering these factors **Sorentino's Kinetic Test Method** (SKT)[8] was developed and a new qualification diagram (Fig. 1) for estimation of nature of aggregate was defined.

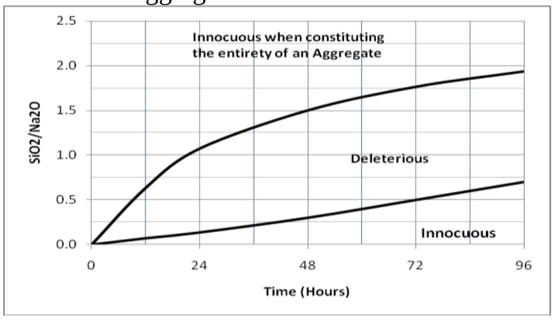


Fig. 1 Interpretation Diagram of the Kinetic Test

The experimental values of silica release (Sc) and sodium concentration are expressed in the form of their molar ratio (SiO_2/Na_2O) as a function of time. In the new diagram three areas were assigned for different type of reactivity. The separation lines have been established on the basis of field performance record of the materials and / or on the results of the concentration expansion test at 38^0C for mortar bar test for fine aggregates, concrete prisms tests for the coarse ones.

A New Approach

SKT with following modifications (NSKT) was adopted for the present study for characterisation of the aggregate.

- Tests were conducted on samples with

(i) Grain size of materials (150µm to 300µm), as per CM
(ii) Grain size of materials (60% of 150µm to 300µm and 40% passing 150µm), as per SKT
(iii) Grain size of materials (passing 150µm),

II. MATERIALS AND METHOD

Six Genesis rock type samples from 3 different hydroelectric projects (Fig. 2) were selected as detailed in Table 1. These samples were subjected to petrographic analysis (PA), Mortar Bar Expansion test (MBE)[9] and CM as per BIS code, SKT and NSKT

Fig. 2 Sampling Location

Table 1: Details of collected Aggregate Samples

Sl. No.	Name of Project	Rock Type	Sample No.
1.	Nathpa Jhakri Power Corporation, HP	Garnet Mica Genesis	1
		Biotite Genesis	2
2.	Kirthai HE Project, J&K	Quartz Mica Genesis	3
		Genesis (mylonitised)	4
3.	Hirakud Dam Project, Orissa	Mylonitized Feldspathic Genesis	5
		Genesis (Feldspathic)	6

III. RESULTS AND DISCUSSION

Petrographic Examination

The result of PA is presented in Table-2. Sample no. 1, 2, 3, 5 and 6 have more than 40% of strained quartz[10,11] and angle of Undulatory Extinction greater than 30^o[11].

Mortar Bar Expansion Test

The results of MBE are presented in Table 3. Sample no. 1, 4, 5 and 6 shows more than 0.06% expansion in six months while sample no. 2 and 3 show expansion less than 0.05%.

Chemical Test

Chemical tests as per CM, SKT and NSKT methods were performed on all the six samples. Reduction Rc, Sc, remaining Na_2O concentration in millimoles/litre in 1 N NaOH solution and ratio of SiO_2/Na_2O are observed for each sample. The results are presented in Fig. 3a-3f, 4a-4f and 5a-5f.

IV. INTERPRETATION OF RESULTS

In PA the potential alkali reactivity of crystalline rocks is related to the percentage and straining effects in quartz (Gogte, 1973)[9]. Rock aggregate containing 40% or more strongly undulatory, fractured or highly granulated quartz are highly reactive; those with 30 to 40% strained quartz[12] are moderately reactive while the ones with predominantly unstrained or recrystallized quartz are innocuous.

The aggregates showing mortar bar expansion above 0.05% in six months are classified as reactive, while those showing lesser expansion in same period as innocuous (Gogte 1973).

Behaviour of the six aggregate samples as observed through PA, MBE, CM, SKT and NSKT test approaches is summarised in Table 4 .

It is noticed that both Rc and Sc values are increasing with increase in reaction time. The overall reactivity of different matrices is found to be in the following order

Sample with grain size matrix

(100% <150 µ) > (60:40 Mixture of 300 - 150µ & <150 µ) > (100 % 300 - 150 µ)

V. CONCLUSIONS

Following conclusions can be drawn from above test results.

1. The grain size play an important role in the reaction. The fraction less than < 150µ has shown greater reactivity than other two fractions. The amorphous silica is generally lost in the fraction size 300 - 150 µ, hence showed lowest reactivity. The choice of fraction containing a mixture of fraction 300 - 150 µ (60%) and fraction < 150µ (40%) is better to have a representative sample.
2. The reaction time has also impact on reactivity. As we increase reaction time the values of reduction in alkalinity and silica release has generally increase. The aggregates having good amount of strained quartz have shown higher reaction values at higher temperature.
3. Reduction in alkalinity to assess nature of the aggregate where a high value of silica release occurs is found to be ill illustrative where as measuring remaining $N_{a2}O$ concentration in Sodium hydroxide solution after the reaction seems to be much more meaningful in justifying the silica release.

Table 2: Result of Petrographic Examination

Sample No	Mineral Name	Quantity %	Strained Quartz %	Angle of Undulatory Extinction
1	Quartz	30-40	85-90	26-32^o
	Feldspar	45-50		
	Biotite	5-7		
	Muscovite	7-9		
	Garnet	1-2		
2	Quartz	40-45	70-75	26-28^o
	Feldspar	38-40		
	Biotite	10-12		
	Muscovite	4-6		
3	Quartz	60-66	40-42	26-28^o
	Feldspar	18-20		
	Muscovite	8-10		
	Biotite	8-10		
4	Quartz	52-58	8-10	44-46^o
	Feldspar	28-30		
	Muscovite	4-6		
	Biotite	8-10		
5	Quartz	28-30	90-95	38-40^o
	Feldspar	46-48		
	Biotite	5-7		
	Pyroxene	3-4		
	Chlorite	2-3		
	Sericite	5-7		
	Sphene	1-2		
	Calcite	2-3		
	Epidote	1-2		
6	Quartz	30-35	90-95	38-45^o
	Feldspar	46-48		
	Biotite	8-12		
	Chlorite	2-3		
	Magnetite	1-2		
	Sphene	1-2		
	Calcite	1-2		

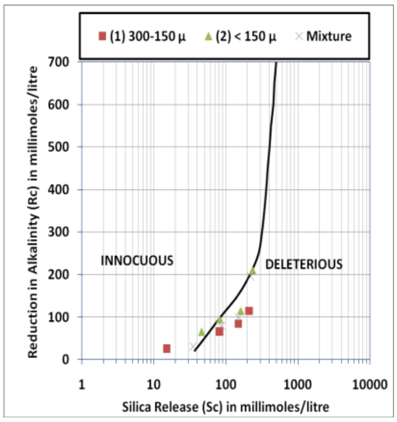
Table 3: Results of Mortar Bar Expansion Test

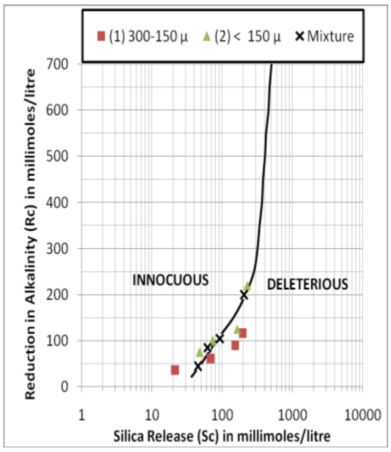
Sl.no.	Sample No	Expansion in % in 6 months
1	1	0.08
	2	0.04
2	3	0.04
	4	0.06
3	5	0.08
	6	0.10

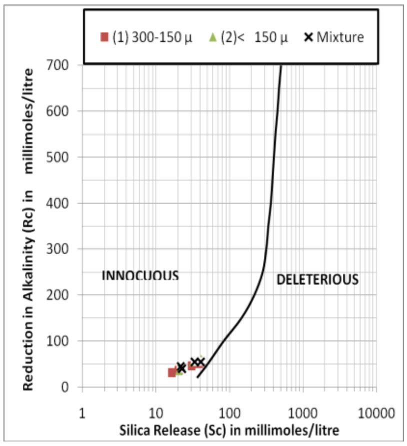
Table 4: Characterisation of Aggregate using Different Tests

Sample No.	PA	MBE	CM	SKT				NSKT											
				Time (Hrs)				Grain Matrix											
								< 150 μ (1)				**150 μ - 300 μ (2)**				**40% of (1) & 60% of (2)**			
				24	48	72	96	Time (Hrs.)				Time (Hrs.)				Time (Hrs.)			
								24	48	72	96	24	48	72	96	24	48	72	96
1	D	D	I	I	I	ID	D	I	D	D	D	I	D	D	D	I	I	ID	D
2	D	I	I	I	I	I	D	I	ID	D	D	I	D	D	D	I	I	I	D
3	D	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
4	I	D	I	I	I	I	I	I	I	D	D	I	I	D	D	I	I	I	I
5	D	D	I	I	I	ID	D	I	D	D	D	I	D	D	D	I	I	ID	D
6	D	D	I	I	I	ID	D	I	D	D	D	I	D	D	D	I	I	ID	D

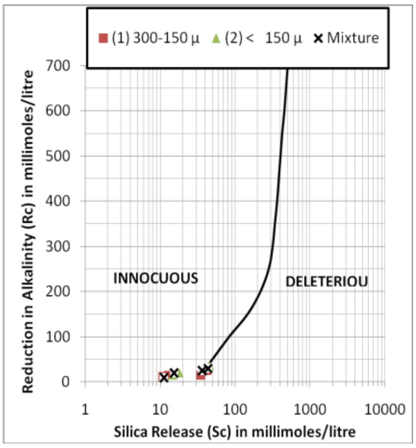
I: Innocuous, ID: On border line of Innocuous to Deleterious, D: Deleterious

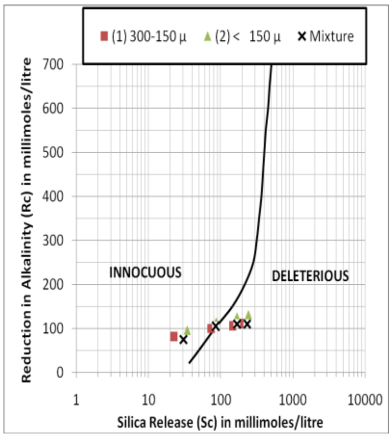


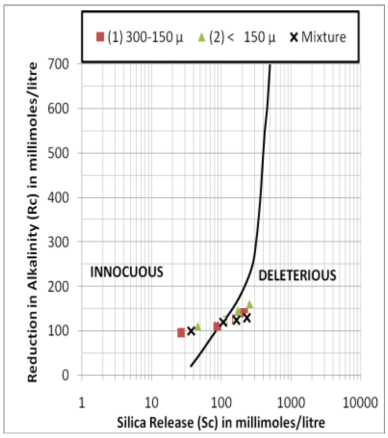




(a) Sample 1 (b) Sample 2 (c) Sample 3

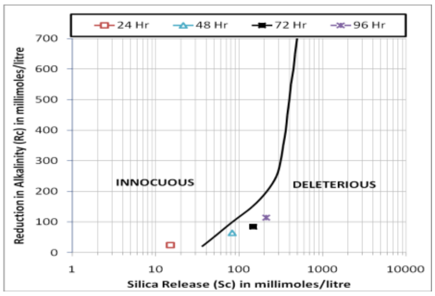


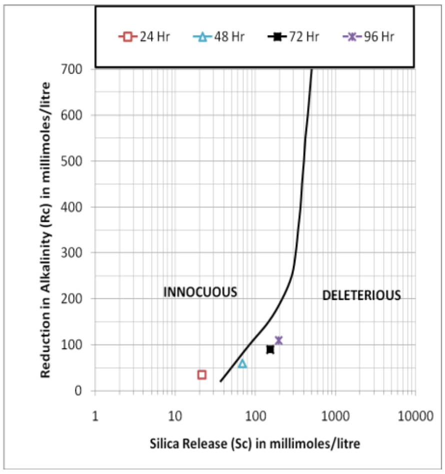


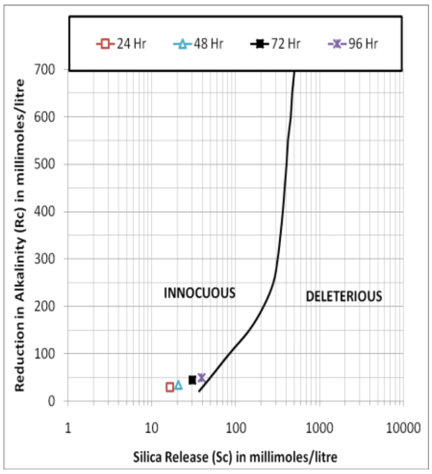


(d) Sample 4 (e) Sample 5 (f) Sample 6

Fig. 3 Charactrisation of Aggregate based on Rc Test on different grain size matrix







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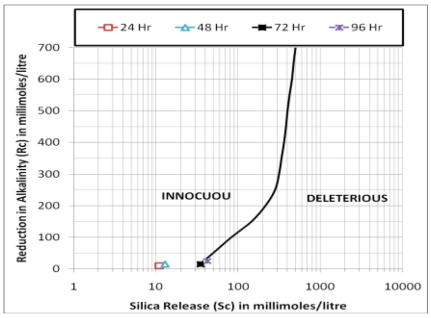
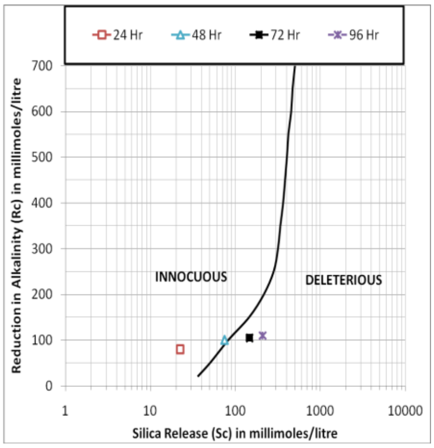
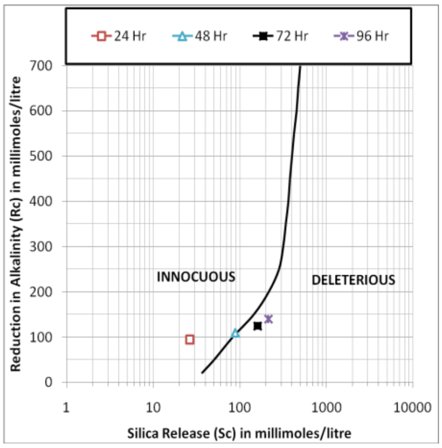
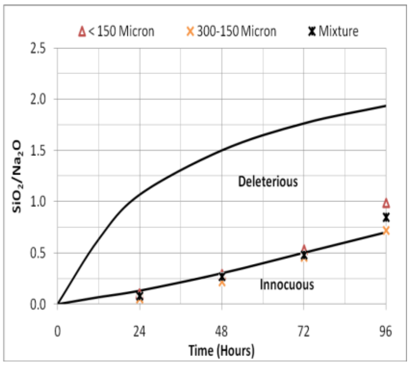


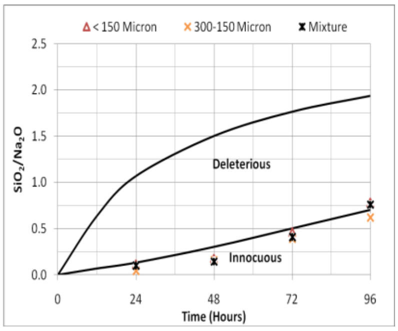


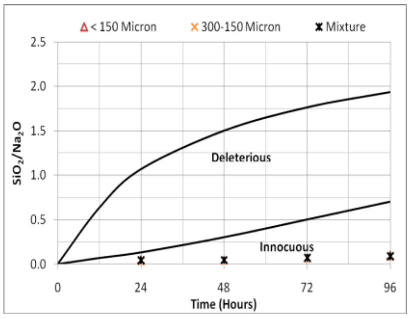


(d) Sample 4 (e) Sample 5 (f) Sample 6

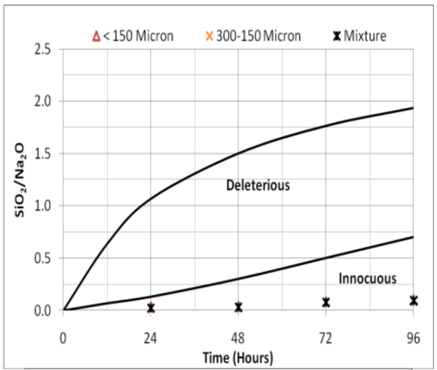
Fig. 4 Charactrisation of Aggregate based on Rc Test on fraction 150 – 300 µ

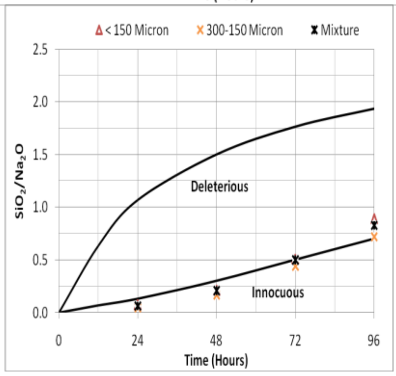


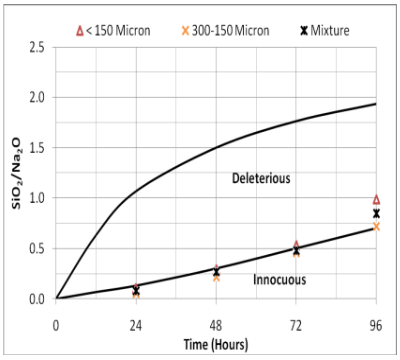




(a) Sample 1 (b) Sample 2 (c) Sample 3







(d) Sample 4 (e) Sample 5 (f) Sample 6

Fig. 5 Charactrisation of Aggregate based on Rc Test on fraction 150 – 300 μas a function of Time

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