THE ASTM C 289 METHOD AND THE KINETIC TEST IN THE STUDY OF ALKALI-SILICA REACTIVITY OF ITALIAN ALLUVIAL DEPOSITS

G. Barisone & G. Restivo
Dip. Georisorse e Territorio, Politecnico di Torino,Cso Duca Abruzzi 24,
10129 Torino, Italy

ABSTRACT

The authors carried out, from 1984 to 1993, a wide program of study on the alkali-silica reactivity of Italian alluvial deposits. The study involved all the Italian peninsular territory south of river Po; over 300 samples were collected, and their reactivity was studied by means of petrographic (ASTM C 295) and chemical (ASTM C 289) methods. It appeared that, unless the almost constant presence of flint as the main reactive mineral, the chemical method was often unable to correctly distinguish among alluvia with different flint contents (and this also after the elimination of carbonates before testing). It was so decided to re-examinate the samples studied using the kinetic test, in order to verify if it was possible to obtain a better correspondence between petrographic and chemical results. The work is still in progress; here the results obtained for some alluvial deposits of the Adriatic coast, which the experience has shown to be among the most dangerous in Italy, are presented. Unfortunately, the tests carried out showed a very bad reliability among the results of the kinetic test and the potential reactivity, so that the ASTM-C 289, if carried out on the aggregates after the elimination of carbonatic components and if slightly modified in the dangerous limits, appears to be at the moment, and despite to its often uncertain repetitivity, the most reliable chemical method for Italian aggregates.
Keywords: AAR, alluvial deposits, kinetic test, Italy.

INTRODUCTION

The alkali-silica reaction started to be studied in Italy only about fifteen years ago, in connexion with the firsts serious cases of structural damages that occurred in the country, using petrographic (ASTM C 295, even modified) and chemical (ASTM C 289) techniques. In various cases, however, the ASTM C 289 method indicated as non-reactive or low-reactive (Baronio 1984) aggregates having caused structural damages, and confirmed as clearly reactive by optical analyses (Barisone 1985).

In order to better evaluate the reliability of these tests for italian aggregates, a study was carried out (Barisone & Restivo 1992) to compare the two methods cited above; the analysis of over 40 samples (corresponding to 23 alluvial deposits of 16 different rivers of the Italian adriatic coast) has shown on one side the high presence (often over the 5 %) of potentially reactive minerals (mainly flint) in the aggregates , on the other side the scarce reliability and a certain under-estimation of the reactivity by the ASTM C 289 methodology.

It was so decided to use the kinetic test (Sorrentino et al 1991) for a further analysis of the most representative samples already studied, in order to verify the suitability and reliability of this new method in evaluating the potential reactivity of Italian aggregates.

GEO-MINERALOGICAL OUTLINES

All the samples come from actual and recent alluvial deposits, formed by the rivers streaming down from the eastern side of Appennines range (Adriatic italian coast). These deposits are mainly formed by pebbles, gravels and sands originated by the erosion of the sedimentary rocks (limestones, marls, calcareous sandstones) that widely outcrop in the mountains, and whose age varies from Trias to Miocene (Crescenti et al. 1969).

The main reactive mineral found in the alluvia is flint (a mix of cripto and micro crystalline quartz, with variable amounts of chalcedony and, sometimes, opal), that comes from the erosion of chert-rich sedimentary formations, mainly limestones of the Mesozoic "complete series" and sandstones of some Miocenic stages (Langhian, Aquitanian).

SAMPLING AND ANALYSES

The sampling

The samples to be studied were collected, whenever possible, in the stock piles of crushed sand in quarries, in order to obtain a good representativity of the coarse-grained alluvial deposits without collecting huge amounts of material.

Petrographic analysis

It was chosen due to its rapidity and good reliability (Barisone 1984). Each sample, after quartering and carbonates elimination by means of diluted chloridric acid, was sieved in order to obtain eight granulometric classes; each class was examinated by a petrographic microscope, identifying a number of grains progressively increasing at the decreasing of average size dimensions (from about 200 in the 0.500-0.250 mm class to more than 500 in the 0.075-0.040 mm class).

The percentage of the various reactive minerals in each sample was calculated as the ponderate average of the eight determinations. The residue after the chemical attack and the total amount of flint (both referred to the original weight of the sample) are listed in Tab.1.

ASTM-C 289 test

As it is well known, the outlines of this method are (ASTM 1952): a 25-g sample crushed to 0.30-0.15 mm and treated at 80 °C for 24 hours with 25 ml of a 1N NaOH solution; determination on the filtrate of reduction in alkalinity (Rc) and dissolved silica (Sc). It must be noted, however, that the high carbonates content of the alluvia studied would be able to considerably alterate the results of the tests (Fournier & Berubè 1989); to avoid this fact, the samples were preliminarly submitted to a chemical attack with diluted chloridric acid, in order to eliminate the carbonates, and the ASTM C 289 test was made using a weight of residue corresponding to 25 g of the original sample.

The effects of such a treatment on the results of the ASTM C 289 test were verified by means of some untreated samples, on which the test furnished a marked under-evaluation of potential reactivity.

The results obtained by the ASTM C 289 method on treated and untreated samples are synthetized in Tab.1.

Kinetic test

In synthesis, this methodology (Sorrentino et al. 1992) is based, such as the ASTM C 289 method, on the treatment of a crushed sample (25 g) with 25 ml of a 1N NaOH solution at 80 °C. Nevertheless, important differences are: the sample granulometry (0.30-0.00 mm, with about a 40 % smaller than 0.10 mm); the execution of analyses after 24, 48 and 72 hours of etching; the replacing of Rc with the Na_2O solution content; the choice of the SiO_2/Na_2O ratio as reference parameter.

Also in this case the tests were carried out after carbonates elimination, using a weight of residue corresponding to 25 g of the original sample. The results obtained are listed in Tab.1.

Table 1a Petrographic examination, ASTM C 289 and kinetic tests results

Sample	Residue (%)	Petrogr. Flint (%)	ASTM-C 289 Rc (mmol/l)	ASTM-C 289 Sc (mmol/l)	Attack time (h)	Kinetic test Na_2O (mmol/l)	Kinetic test SiO_2 (mmol/l)	Kinetic test SiO_2/Na_2O
3	untr.	7.8	245	30	24			
	37.2		8	150	24	184	115	0.62
					48	195	132	0.68
					72	224	196	0.87
7	12.0	4.0	70	93	24	125	217	1.73
					48	134	251	1.87
					72	139	295	2.12
10	untr.	4.4	117	22	24			
	10.5		33	112	24	193	112	0.58
					48	208	129	0.62
					72	232	188	0.81
18	untr.	8.8	127	19	24			
	15.6		38	302	24	211	55	0.26
					48	224	68	0.30
					72	256	82	0.32
21	43.6	9.4	11	600	24	245	24	0.10
					48	250	66	0.26
					72	271	88	0.32
25	22.8	10.7	35	260	24	214	24	0.12
					48	233	44	0.18
					72	244	95	0.39

Table 1b Petrographic examination, ASTM C 289 and kinetic tests results

Sample	Residue (%)	Petrogr. Flint (%)	ASTM-C 289 Rc (mmol/l)	Sc	Attack time (h)	Kinetic test Na_2O (mmol/l)	SiO_2	SiO_2/Na_2O
29	untr.	17.3	132	37	24			
	28.4		45	143	24	214	8	0.04
					48	233	22	0.09
					72	244	89	0.37
38	untr.	2.5	27	29	24			
	94.4		55	110	24	121	217	1.80
					48	130	251	1.93
					72	133	294	2.21
40	71.6	7.3	42	58	24	227	221	0.97
					48	244	252	1.03
					72	250	316	1.27
42	40.0	13.5	140	146	24	190	16	0.08
					48	218	26	0.12
					72	315	49	0.16
59	64.0	17.5	115	46	24	210	133	0.63
					48	220	163	0.74
					72	249	208	0.84
60	27.6	4.6	115	51	24	244	383	1.57
					48	245	537	2.20
					72	274	614	2.24
62	untr.	14.5	150	12	24			
	67.6		90	130	24	259	155	0.60
					48	267	194	0.73
					72	282	220	0.78
121	25.4	5.4	85	200	24	212	150	0.70
					48	241	186	0.77
					72	256	199	0.78
124	9.9	1.6	75	110	24	110	220	2.00
					48	115	253	2.20
					72	132	306	2.32

The ASTM-C 289 method and the Kinetic test require both, to classify the degree of risk of the aggregates tested and the placement of the data in diagrams. In our case, the great number of points to be placed could cause a bad readability of these diagrams, so it was decided to simply point out, in the following Tab.2, the potential reactivity showed by the alluvia examined by means of the three testing methods used (optical, ASTM and Kinetic).

It must be remembered that the potential reactivity is not strictly corresponding to dangerousity, this parameter being almost null for low and very high reactive minerals content. So, the aggregates classed in table 2 with a potential reactivity low or high are normally classed as innocuous in the dangerousity diagrams.

Table 2 Potential reactivity of the aggregates tested with optical, ASTM and Kinetic methods

Sample	River	Potential reactivity Optical	ASTM	Kinetic	Sample	River	Potential reactivity Optical	ASTM	Kinetic
3 *	Biferno	M	M	M	40	Santerno	M	L	M
7 *	Sangro	ML	ML	H	42 *	Sillaro	H	L	L
10	Pescara	ML	ML	M	59	Fortore	H	L	M
18	Salinetto	MH	M	L	60 *	Cervaro	ML	L	H
21	Tronto	MH	MH	L	62	Ofanto	H	ML	M
25	Chienti	MH	M	L	121 *	Trigno	M	ML	M
29	Esino	H	ML	L	124	Treste	L	ML	H
38	Lamone	L	ML	H					

Potential reactivity: L = low, M = medium, H = high
Optical tests. Flint: < 3 % = L, 3÷6 % = ML, 6÷8 % = M, 8÷12 % = MH, > 12 % = H
* Rivers whose aggregates surely caused structural damages

CONCLUSIONS

The tests carried out show a fairly satisfactory correlation between the results furnished by optical and ASTM-C 289 methods, correlation that would be good slightly changing (moving rightward) the lower part of the separation curve between the "innocuous" and "deleterious" fields in the ASTM diagram.

On the contrary, the kinetic test results are unsatisfactory, mainly for the aggregates with very low and very high flint contents, that are normally respectively classed as highly and lowly reactive (and, for the high flint contents, with very low amounts of dissolved SiO_2).

The study is still in progress, and the data collected are for the moment in a reduced number; nevertheless, the ASTM-C 289 method once more proved to be the most reliable chemical method (in spite of its scarce reproducibility, perhaps due also to the high variations in the composition of the alluvia sampled and to the reduced weight of the samples tested, not always representative in spite of the accuracy in quartering) for potential reactivity testing of aggregates having, as the italian ones, a low ratio between the reactivity degree and the flint content.

REFERENCES

ASTM 1952, 'Standard method of test for potential reactivity of aggregates (Chemical method)', Annual book of ASTM standards.

Barisone, G. 1984, 'Petrographic analysis of aggregates related to alkali-silica reaction', Proc. Symp. Int. sur les granulats, Nice, Bull. I.A.E.G., 30.

Barisone, G. 1985, 'Gli inerti per calcestruzzo ed il fenomeno dell'alkali-silica reaction sul versante adriatico dell'Italia centro-meridionale', Proc. III Conv. Naz. "Attivita` estrattiva dei minerali di 2° categoria", Bari

Barisone, G. & Restivo, G. 1992, 'Alkali-silica reactivity of alluvial deposits evaluated using chemical and psammographic methods', Proc. IX Int. Conf. on Alkali-aggregate reaction in concrete, London.

Baronio, G. 1984, 'Granulats reactifs aux alcalis utilisés en Italie', Proc. Symp. Int. sur les granulats, Nice, Bull. I.A.E.G., 30.

Crescenti, V. & Crostella, A. & Donzelli, G. & Raffi, G. 1969, 'Stratigrafia della serie calcarea dal Lias al Miocene nella regione Marchigiana-Abruzzese', Mem. Soc. Geol. It., 8.

Fournier, B. & Berubè, M.A. 1989, 'Alkali-reactivity potential of carbonate rocks from the St. Lawrence lowlands (Quebec, Canada)', Proc. VIII Int. Conf. on Alkali-aggregate reaction, Kyoto.

Sorrentino, D. & Sabio, S. & Junique, D. 1991, 'Attaque alcaline des granulats: mise au point d'un test cinétique', Annales ITBTP, 499, Série Essais et mesures, 235.

Sorrentino, D. & Clement, J.Y. & Golberg, J.M. 1992, 'A new approach to characterize the chemical reactivity of the aggregates', Proc. IX Int. Conf. on Alkali-aggregate reaction in concrete, London.