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ALKALI-SILICA REACTIVITY OF SOME ITALIAN OPAL AND FLINTS TESTED USING A MODIFIED MORTAR BAR TEST

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ABSTRACT

In order to determine the reasons for low reactivity and to evaluate the pessimum percentages of Italian flints in aggregates, starting in 1984 the authors carried out chemical, petrographic and physical tests; among them, the Mortar Bar Test (ASTM C 227) was used.

To reduce the duration of the test (while maintaining test conditions rather similar to reality) and to better approach the grading distribution normally used for concrete, some variations to ASTM C 1293 (and ASTM C 1260) were experimented with in the last three years. In particular, the dimensions of mortar bars and the aggregate size were increased, and the storage conditions were modified.

The aggregates were made by mixing a crushed limestone (99.7% calcite) with different percentages of opal or flint; during two years of experiments, 54 samples were tested following the modified test, 27 (control samples) were also evaluated following the ASTM C 1293 procedures.

The results showed a rather good representativity of the modified test, with an expansion after one month similar to the expansion of ASTM C 1293 after one year; the reactivity degree of the samples varied from very low to medium for the flints, very high for the opal. The pessimum percentage (i.e. the percentage of reactive minerals corresponding to the maximum expansion was about 7% for flints, 1-2% for opal.

Keywords: Alkali-aggregate reaction, reactive minerals, Italy, modified mortar bar test, opal, flint.

INTRODUCTION

Italian flints, notwithstanding their frequent presence in many sedimentary rocks (mainly limestones) largely outcropping in the Italian peninsula south of river Po, caused relatively little damage to concrete structures due to the alkali-silica reaction.

In order to evaluate the reasons for such a low reactivity and to determine the pessimum percentage of these flints in aggregates, the authors begun to carry out, in the eighties, a series of studies to evaluate the reactivity degree of Italian aggregates (Barisone 1985, Barisone et al. 1986, Barisone et al. 1994) and to compare the reactivity of different flints (Barisone and Restivo 1996).

Chemical tests proved unreliable in detecting Italian reactive aggregates (Barisone and Restivo 1992). The Mortar Bar tests (ASTM C 227) carried out by the authors and by other researchers also often provided ambiguous results (Alunno Rossetti et al. 1988).

To better evaluate the degree of reactivity and the pessimum percentage of Italian flints in aggregates, a program based on the ASTM C 1293 and on a somewhat original accelerated procedure was carried out.

SPECIMENS MANUFACTURE

The specimens used both for the ASTM C 1293 and the modified test were made by mixing, to an aggregate obtained from an almost pure limestone (99.7% of $CaCO_3$), different percentages of crushed reactive minerals (opal or flint). The reactive minerals used, collected in situ, were:

- Flint nodules of Cretaceous and upper Miocene age, coming from the alluvial deposits of the Pescara river (Abruzzo); no cases of structures made with these aggregates and damaged by the AAR are known.
- Flint nodules of Paleocene and lower Miocene age, coming from the alluvial deposits of the Biferno river (Molise); serious damage due to AAR occurred in late eighties to several structures made using these aggregates.
- Opal lenses in altered serpentinites (Quaternary pedogenetic alteration) near Turin (Piemonte).

For each reactive mineral, 27 samples were made, subdivided in 9 classes, corresponding respectively to a reactive mineral content of 0.2 %, 0.5 %, 1 %, 3 %, 5 %, 7 %, 10 %, 15 %, 20 % by mass. In each class, one control specimen was made following the requirements of ASTM C 1293, the two others following the procedures described below for the accelerated test.

In order to better approximate the real conditions of concrete structures, the mortar bars dimensions were increased, for the accelerated test, to 500 mm in length and with a square section of 100x100 mm. The concrete was made using a 425 Portland cement with a 1.08 % content of alkali equivalent (Na_2O = 0.45 %, K_2O = 0.90 %), with a dosage of 470 kg/m^3 (corresponding to almost 5 kg/m^3 of alkali equivalent); the water-cement ratio was 0.4.

The granulometric composition was also changed, increasing the coarser classes (limestone) from 35 % to 50 %; the granulometry of crushed reactive minerals was reduced, but varied among the samples (A) with a low reactive mineral content (≤ 1 %) and the others (B) (See Table 1).

TABLE 1: Granulometry of aggregates for Modified test

Calcitic sand [%]	Granulometry [mm]	Reactive minerals [%] samples A	B
20	5÷2	-	-
30	2÷1	-	-
25	1÷0.6	40	50
15	0.6÷0.3	30	30
10	0.3÷0.1	30	20

THE MODIFIED TEST

In order to accelerate the alkali-aggregate reaction, but wishing to avoid test conditions too different from those normally occurring to concrete structures, the test was made by keeping the specimens alternatively for five days in a water vapour saturated atmosphere at a temperature of 50°C and for two days in an atmosphere of 40 % humidity and at 20°C.

Before starting the test, that was lengthened to about six months, the specimens were stored for twenty days at 20°C and 60 % humidity following de-moulding. After this period, and the zero measurement done, the expansion was measured weekly, with an accuracy of 0.001 mm, using stainless reference marks placed on the four sides of the concrete prisms, at a distance of about 40 cm.

RESULTS AND CONCLUSIONS

The results, shown in Table 2 and Figures 1,2 and 3, can be considered under two aspects: the reliability of the accelerated test carried out, and the reactivity and the pessimum percentage of some Apennine's Italian flints.

The accelerated test described in this research showed a good ability to distinguish the different degree of reactivity of the Apennine's flints. With some exceptions, the expansions measured after 1 month were normally close enough to those registered after 6 months.

Probably due to the coarser granulometry, the results obtained with our test are normally a little (10÷20 %) lower then those shown by the ASTM C 1293 in the case of highly reactive minerals, while for minerals with a low reactivity the agreement is very good (See Table 2).

Although the reliability of this accelerated test appears good, as is its capability to discriminate among Italian flints with a degree of reactivity varying from medium to very low, the considerable amount of aggregates required to make specimens and the care needed in the manufacturing of the samples make this method normally more arduous than ASTM C 1260 or the other common accelerated tests (Thaulow and Olafsson 1981, Criaud et al. 1992, Shayan et al. 1992).

TABLE 2: Measured concrete prism expansion [‰]

Reactive mineral cont.			0.2 %	0.5 %	1 %	3 %	5 %	7 %	10 %	15 %	20 %
Pescara River Flint	Acc. Test	1 week	0.02	0.05	0.08	0.11	0.12	0.14	0.13	0.08	0.10
		2 w.	0.06	0.09	0.14	0.13	0.18	0.18	0.18	0.09	0.12
		1month	0.07	0.15	0.18	0.14	0.19	0.24	0.22	0.13	0.12
		3 m.	0.08	0.16	0.18	0.16	0.19	0.24	0.24	0.15	0.12
		6 m.	0.08	0.16	0.19	0.19	0.19	0.25	0.24	0.16	0.12
	ASTM C1293	1 year	0.07	0.12	0.19	0.18	0.24	0.32	0.28	0.20	0.20
Biferno River Flint	Acc. Test	1 week	0.15	0.27	0.24	0.45	0.54	0.63	0.39	0.24	0.18
		2 w.	0.18	0.30	0.36	0.63	0.66	1.02	0.77	0.27	0.30
		1month	0.21	0.54	0.60	0.75	0.94	1.44	0.99	0.51	0.39
		3 m.	0.24	0.63	0.69	0.79	1.14	1.74	1.02	0.53	0.42
		6 m.	0.24	0.65	0.72	0.81	1.26	1.93	1.06	0.54	0.42
	ASTM C1293	1 year	0.27	0.63	0.93	1.27	1.46	2.43	1.16	0.54	0.31
Turin Opal	Acc. Test	1 week	0.80	1.72	3.24	5.61	4.86	3.32	2.83	0.87	0.84
		2 w.	1.41	1.83	7.26	21.6	11.5	4.46	2.63	1.75	1.01
		1month	1.70	2.71	8.84	23.4	16.4	4.69	3.24	1.96	1.23
		3 m.	1.78	3.36	8.52	23.5	17.1	5.74	3.36	1.96	1.27
		6 m.	1.82	3.84	11.8	23.5	17.5	12.7	3.71	1.97	1.29
	ASTM C1293	1 year	2.10	4.60	13.5	28.6	22.4	18.1	5.30	2.70	1.60

The results confirm the very low degree of reactivity of Apennine flints from North of Sangro river and the medium reactivity of those from South of this river. This in spite of the difficulty found to differentiate among them (Barisone and Restivo 1996). The reactivity of Quaternary opal (here used mainly to verify the test with a material with a high reactivity) was very high, as expected.

The pessimum percentages of these minerals in an aggregate range from 7 % to 10 % for the low reactive flints (alluvial deposits of Pescara and other rivers in Emilia, Romagna, Marche and Abruzzo regions), from 5 % to 7 % for the medium reactive ones (alluvial deposits of Biferno and other rivers of Molise and northern Puglia), and around 3 % for the opal of some quaternary deposits near Turin.

Fortunately, the flint content of natural alluvial deposits of the above mentioned rivers is normally lower than 7 %, making these aggregates potentially harmful only in the case of the more reactive flints (Biferno and similar rivers) or of anomalous concentrations of the reactive mineral in the alluvium.

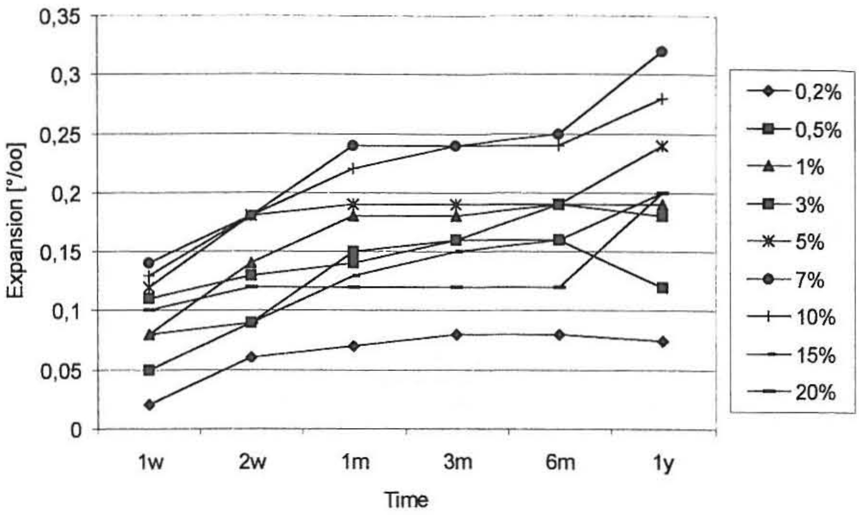

Fig. 1: Plot of concrete prisms expansion for different percentages of Pescara river flint.

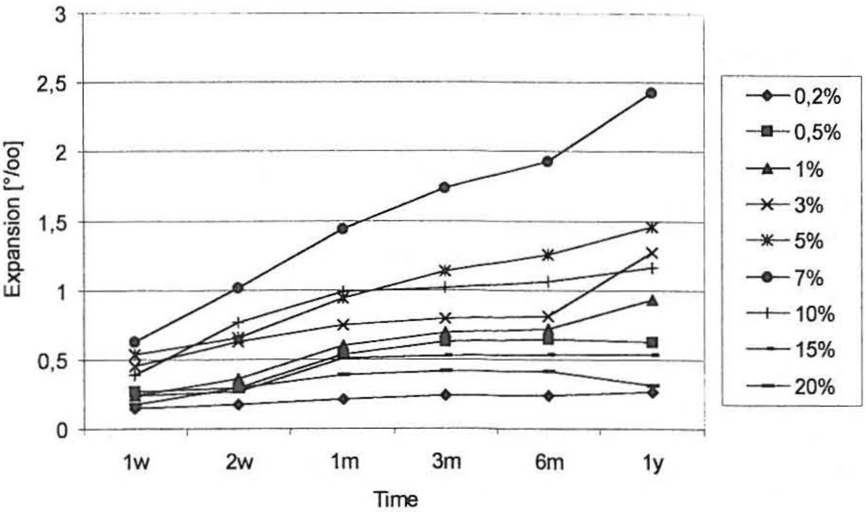

Fig. 2: Plot of concrete prisms expansion for different percentages of Biferno river flint.

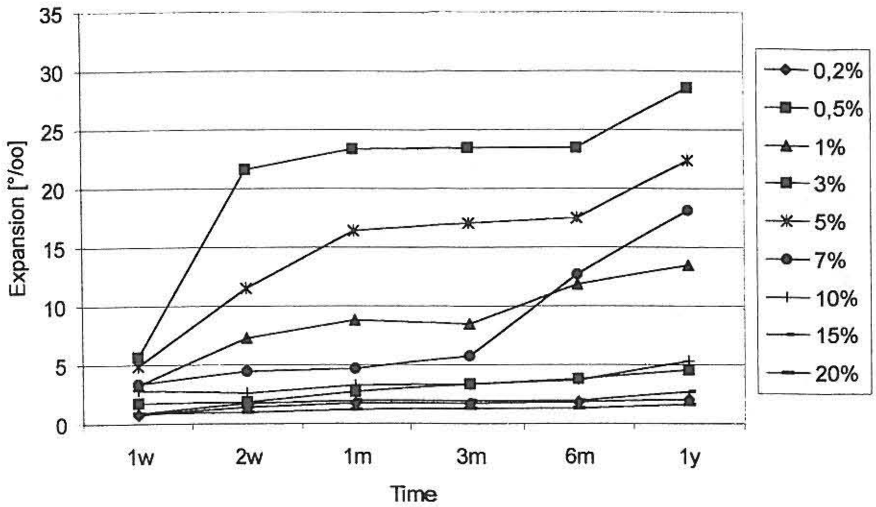

Fig. 3: Plot of concrete prisms expansion for different percentages of Turin opal.

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