

# The Potential Alkali-Aggregate Reactivity in Italy: Comparison of Some Methods to Test Aggregates and Different Cement-Aggregate Combinations

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## ABSTRACT

The alkali reactivity of an Italian aggregate, coming from an area where severe alkali-aggregate reactions recently occurred, was evaluated by petrographic and chemical analyses, infrared spectroscopy and gel-pat tests. In addition, combinations of this aggregate with three Portland cements with increasing alkali content were tested in mortars and concretes according to ASTM, RILEM and Canadian test methods.

A comparative, critical analysis of the results made it possible to select the test methods that best characterize the potential alkali reactivity of Italian cement-aggregate combinations.

## INTRODUCTION

In the past few years, several cases of alkali-aggregate reaction in concrete were found in Italy, both in residential and industrial buildings (Baronio 1983 and Levi et al. 1985) and in industrial pavements where pop-outs had occurred (Rossetti 1981).

As regards aggregate origin, the most critical geological area was found to be that of the Adriatic coast (Baronio 1984), where most reaction cases were located.

However, since a wide range of cement types is available in Italy, the most appropriate type can be chosen to minimize the effects of this reaction (blast-furnace slag, fly-ash, pozzolanic cement, etc.) (Berra 1983).

The purpose of this study is to select, among the many existing test methods, those which best characterize the potential alkali reactivity of Italian aggregates in mortars and concretes and the reactivity of cements.

TEST MATERIALS AND METHODS

Several types of Portland cement currently produced in Italy and of different classes of strength were taken into consideration and analyzed. Three of these were selected and are referred to herein as cements No.1, 2 and 3, having 0.62%, 0.88% and 1.23% alkali content, measured as  $\text{Na}_2\text{O}$ -equivalent (total acid-soluble alkali as per ASTM C 114), and belonging to the strength classes 425, 525 and 425 respectively. The soluble silica was determined as per UNI 6505, which yielded 16.08%, 17.18%, 17.44%. These values might be taken as evidence of raw mineral addition to the clinker.

The aggregate used, in different size ranges, came from an area where severe alkali-aggregate reactions were recently found. Petrographic analysis of the aggregate yielded the following composition: 80-85% sedimentary limestone, containing such impurities as clay and fossil residues; 15-20% pure sedimentary limestone; 0.5-1% chert.

According to the ASTM C 289 chemical method, some of the size ranges being tested are to be considered innocuous, while others are potentially deleterious. On the other hand, infrared spectroscopy (Hirche 1975 and Bachiorrini 1987) produced an average "Coefficient of disorder" (Cd) of 203, which, according to recent research (Bachiorrini et al. 1986) indicates short-time potential reactivity.

This reactivity was confirmed by gel pat tests (British National Building Studies 1958) on the three types of cement under examination. Sulphate content was low, varying from 0.02 to 0.05%  $\text{SO}_3$ .

Starting with the above materials, the authors tried to detect and evaluate the alkali-aggregate reaction by submitting the aggregate to several laboratory tests with different cement-aggregate combinations in mortars and concretes, to determine the tests most suitable to characterize the aggregate's potential reactivity in combination with cement.

Expansion tests on mortar bars by ASTM C 227 and by the method recommended by the Rilem Technical Committee 26 GM (Rilem Technical Committee 26 GM 1982), and expansion tests on concrete specimens to Canadian Standard CAN3-A23.2-M77 were performed. Finally, optical analyses on thin sections at the cement paste-aggregate interface and micro-analyses of the reaction products were carried out.

RESULTS

Figs 1, 2 and 3 show the results of the different expansion tests. Fig. 1 shows the expansion values by ASTM C 227 on mortar bars made with the cements No. 1, 2 and 3.

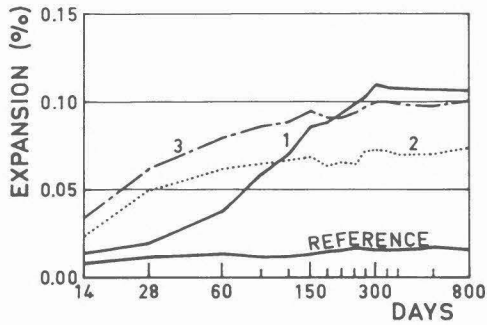


Fig. 1 - Expansion of mortar bars according to ASTM C 227.

Fig. 2 shows the expansion of mortar bars made with the same three cements using the method recommended by Rilem for the suggested mixtures of reactive aggregate and non-reactive sand (Italian standard sand from Torre del Lago).

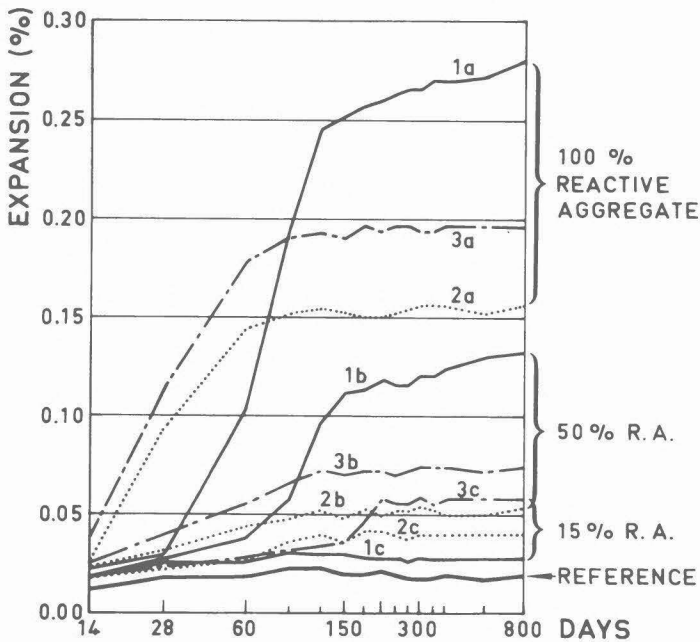


Fig. 2 - Expansion of mortar bars according to the Rilem Technical Committee 26 GM recommendations (a: cement combined with 100% reactive aggregate; b: cement combined with 50% reactive aggregate; c: cement combined with 15% reactive aggregate).

Fig. 3 shows the expansion of concrete specimens tested by the Canadian Standard mentioned above, with two size ranges (5-10<sub>3</sub> and 10-25 mm) of reactive aggregate and the three cements at about 310 kg/m<sup>3</sup> content.

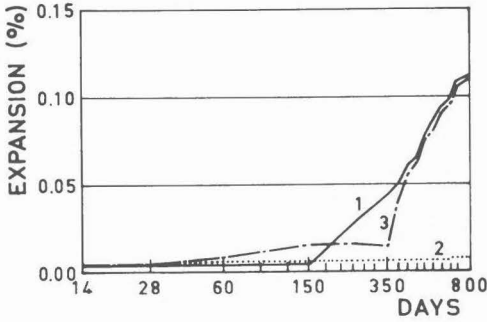


Fig. 3 - Expansion of concrete specimens according to Canadian Standard CAN3-A23.2-M77.

Optical analyses on thin sections showed alteration of the chert particles and the presence of a whitish, isotropic ultrafine material in the pores of the mortar (Fig. 4).

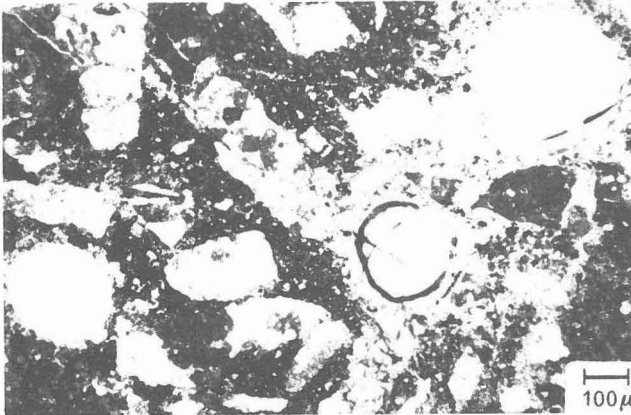


Fig. 4 - Mortar pores and cracks filled with whitish, isotropic ultrafine material.

Micro-analyses of the reaction product from the mortar made with cement No.3 (with the highest alkali content) yielded  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  contents of 0.33% and 2.10% respectively.

The alkali values of the reaction products from the gel pat test were higher ( $\text{Na}_2\text{O} = 7.26\%$ ;  $\text{K}_2\text{O} = 4.8\%$ ), as expected.

## DISCUSSION

The mortar expansion values obtained with the method recommended by Rilem (Fig. 2) permit to evaluate, at least approximately, the maximum percentage of reactive aggregate that can provide expansion values within a preset threshold in combination with a specific cement.

For example, this threshold can be set at 0.05%, which equals about twice the maximum expansion measured on mortars containing no reactive aggregate. Thus it can be observed that, except for mortar bars containing higher alkali cements, the reactive aggregate tested can be used without trouble at percentages of up to 15% by weight of total aggregate. Therefore, reactive aggregates can be used, when necessary and provided they are properly diluted, for concrete mixes.

The different expansion values of mortars tested by the method recommended by Rilem (with 100% reactive aggregate) and by ASTM C 227 can be explained by the different sizes of the mortar bar (4x4x16 cm in the first case; 2.5x2.5x28.5 cm in the second) and by greater warping in the second case.

However, the expansion behaviour is similar (Figs 1, 2).

It can be noticed that the mortars made with cement No. 1 (which has the lowest alkali content) reach higher expansion values than the other mortars in very short time, after an initial standby period. Such performance suggested that the alkali content of the cements be re-determined according to DIN 1164 concerning raw mineral addition. The analysis showed the alkali content of the three types of cement to be 2.1%, 1.4% and 1.6% of  $\text{Na}_2\text{O}$  equivalent, while the total alkali according to ASTM C 114 was 0.62%, 0.88% and 1.23%.

The higher alkali content of cement No. 1 against the others could explain the delayed expansion of these mortar bars, which might be due to the slow dissolution of the alkali originating from raw mineral addition.

Concrete expansion (Fig. 3) is slower than that of mortar but the behaviour is essentially the same, apart from some minor inconsistencies. The results with concrete confirm the higher reactivity of aggregate with cement No. 1.

## CONCLUSION

Deterioration of some concrete structures due to alkali-aggregate reactivity indicates that such phenomena also occur in Italy.

Laboratory tests on a reactive aggregate of Italian origin in combination with different types of Portland cement having progressively higher alkali contents, show that the reaction does not only depend on the alkali from

cement clinker but also on alkali originating from possible raw mineral addition, which cannot be detected by conventional cement test methods (ASTM, UNI).

Among the tests used to characterize the aggregate, the chemical method ASTM C 289 was found to be unreliable, while infrared spectroscopy seems more promising. As regards evaluating the reactivity of cement-aggregate combinations, the mortar bar method suggested by Rilem appears to be the most exhaustive; this method also allowed us to ascertain the tolerable amount of reactive aggregate in combination with the cements tested.

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