Reactivity of Alkalis and Sandstones Cemented with Opal and Chalcedony

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INTRODUCTION

In Argentina the occurrence of damage in a pavement, in 1958, gave rise to the first systematic studies on alkali-aggregate reactions. The detection of this reaction in other structures and its technical-economical importance in relation to future construction gave rise to the creation of a Commission for the Study of the Alkali-Agregate Reaction, in 1964.

This Commission studied more than 400 sources according to ASTM methodology. These and other studies done by private and official institutions defined from petrographic analysis three zones with potentially reactive aggregates; Figure 1 shows the three zones. According to these studies, 5 per cent of all the aggregates which petrography indicated to be potentially reactive, really showed deleterious expansion.

In zone I there are three potentially deleterious materials:

- Tholeite - basalt.
- Gravel from the Uruguay river and sands from the Parana river (reactivity due to soluble silica).
- Sandstones cemented with opal and chalcedony.

This paper considers exclusively concretes containing sandstones cemented with opal and chalcedony. Some examples of deteriorated structures and the corresponding studies are presented.

ANTECEDENTS

* Concrete block for electromotor base (structure A): In 1977 cracking appeared on a concrete block two years old; 30°C and high moisture were the mean environment conditions (1).
* International airport (structure B): In 1978 some deterioration took place on the 130.000 m^2 international airport constructed during 1960. The thickness of the airstrips were 0,45 and 0,30 m. 21°C and a

rainfall of 1250 mm are the mean annual conditions of this subtropical climate (2).

* 500 Kv. transmission line (structure C): In 1984 cracking in foundations of a tranmission line appeared 8 years after construction (Figures 2 and 3) (3).

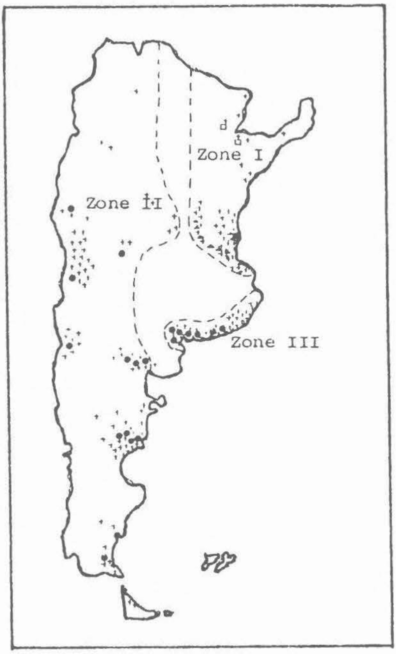

Figure 1

Potentially reactive aggregate in Argentina (ASTM methodology)

+Potentially reactive by petrography

Reactive by ASTM-C-227
- ◻ For opal
- • For volcanic glass
- Δ For opal in chalcedony

STUDIES AND RESEARCH

The characteristics of hardened concrete were evaluated (cement content, density, absorption, compressive strength, elastic modulus and alkali content). Aggregates employed were petrographically identified.

Ultrasonic pulse measurements and crack maps (Figure 4) were made on structure C. Extremely cracked zones were found in the mass concrete, no conlcusions could be drawn from ultrasonic pulse velocity measurments.

1. Characteristics of hardened concrete

Table 1 shows the concrete characteristics of the four structures. Water soluble alkali at (24 hrs) and hydrochloric acid soluble alkali contents were determined. The values obtained represent residual alkalis, that have neither reacted with aggregates nor have been washed by rain. Moreover it must be noted that the values determined on hardened concrete samples are always lower than the alkalis calculated from the cement content.

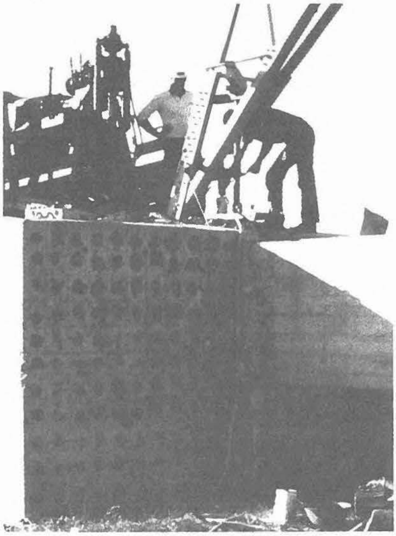

Figure 2: Foundation of a transmission line (structure C).

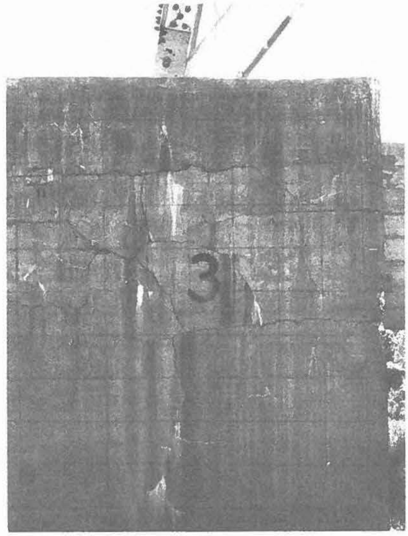

Figure 3: Details of cracks in structure C.

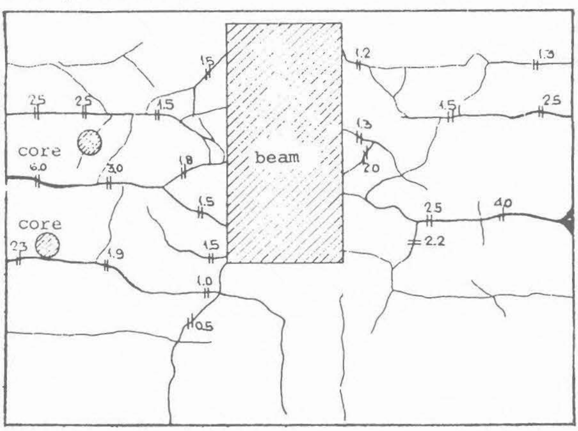

Figure 4: Map of cracks (structure C)

Table 1: Concrete characteristics

Structures	Specific Gravity	Absorption (%)	Cement content (Kg/m^3)	Compressive strength (MPa)	Static modulus (GPa)	Alkali soluble in (%) water	HC1
A	2.31	10.0	---	7.0	4.0	---	---
B	2.37	---	350	22.1	18.0	0.02	0.10
C	2.34	7.1	435	29.5	24.2	0.04	0.10

Values of compressive strength and static modulus of elasticity of structure B and C were determined on samples without visible cracks. In structure A they correspond to specimens with visible cracks.

2. Petrographic characterization of aggregates.

The petrography of the aggregates is shown in Table 2. Chalcedony is present in sands of structures B and C. The chalcedony in this area does not show reaction with alkalis. Research carried out with sands with different contents of chalcedony had expansions smaller than 0,1 per cent (Figure 5); neither gel nor cracks were observed (5).

Table 2: Petrographic characteristics of aggregates.

Structures	Aggregates	Minerals	%
A	Fine	Quartz	100
	Coarse a	Migmatite	80
	Coarse b	Sandstone cemented with opal	20
B	Fine	Quartz	96
		Chalcedony	4
	Coarse	Basaltic	
		Quartz	*
		Sandstone cemented with opal	
C	Fine	Quartz	90
		Chalcedony	10
	Coarse	Quartz	24
		Chalcedony	44
		Limonite	12
		Sandstone cemented with opal	20

* Not determined.

Coarse aggregate used in structures A and B was crushed stone, that used in structure C was gravel. The three materials contained sandstone cemented with opal and chalcedony. Observations realized on samples obtained from the structures showed that sandstone particles had reacted with alkalis. Reaction products were identified by visual, chemical and X-ray techniques.

In addition, we can say that this sandstone, when used alone, has not caused expansion, possibly because of a pozzolanic effect. See Table 3 (5).

Table 3: Mortar bar expansion of sandstone cemented with opal and chalcedony.

Cement	Months			
	1	3	6	12
High alkali	-0.003	0.005	0.023	0.020
Low alkali	-0.014	-0.007	0.012	-0.032

On the contrary, research done with non reactive aggregates to which were added different percentages of opal, showed maximum expansions with 6 per cent and 2 per cent opal using cements with alkali contents (Na_2O eqv) of 1,15 per cent and 0,46 per cent respectively. See Figure 5.

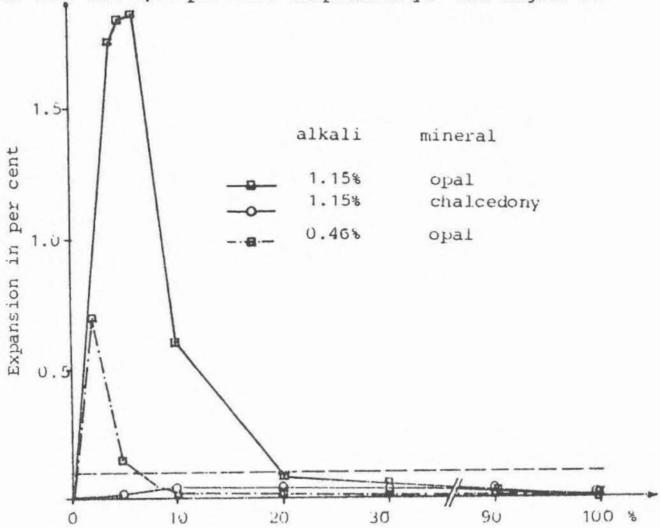

Figure 5: Expansions of mortar bar with variable percentages of opal and chalcedony.

CONCLUSIONS

a) We have verified deleterious expansions due to alkali-silica reactions of tholeitic basalts.

b) Chalcedony contained in gravels and sands of the Parana and Uruguay rivers is not reactive. These gravels have potential reactivity due to opal.

c) Sandstone particles included in gravels of the Parana and Uruguay rivers and others obtained from quarries situated in Chaco (Argentina) are reactive. They produce deleterious expansions when their opal content is near the "pessimum" in the total of the aggregate.

d) The presence of opal in the rocks mentioned in b) and c) can be discovered through optical microsocpy and X-ray diffraction.

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