# PETROGRAPHY OF POTENTIALLY ALKALI-REACTIVE SANDSTONE FROM ARGENTINA

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**Abstract**

Petrographic characteristics of sandstone from the Province of Corrientes, Argentina, were studied. The rock has been classified as potentially alkali reactive in previous work using the accelerated mortar bar test method (ASTM C 1260). The average expansion was 0.337% at 16 days and 0.432% at 28 days.

Moreover, the concrete prism test (ASTM C 1293) was used. The expansion measured at 1 year was 0.074%, exceeding, at 4 weeks, the limit established for 1 year (0.040%).

The rock was classified as quartzose sandstone. The cement is chalcedony, cristobalite, opal and cryptocrystalline quartz, all of them potentially alkali reactive.

The study made in fragments of the mortar bar, determined that particles near the surface have no cement, forming an unconsolidated aggregate. Cracks are abundant, affecting the lithological components and the mortar. Siliceous cement in the aggregate particles has been leached, and silica is deposited mainly in voids. The mortar microstructure was studied by SEM-EDS in order to evaluate the characteristics of the deleterious reaction.

**Keywords**: Sandstone, amorphous and/or cryptocrystalline silica, ASR, expansion, fissures.

## 1 INTRODUCTION

The rocks containing amorphous or cryptocrystalline silica react with the alkali hydroxides (K and Na, OH) of the concrete pore solution and cause expansive deleterious reactions that deteriorate concrete structures. In Argentina there are service history records of concrete structures deteriorated by siliceous sandstone in a relatively short time [1,2,3,4,5].

As in the composition of these rocks chalcedony, opal and/or cristobalite are present as cement, they should be considered as potentially reactive. The deleterious reaction is of the fast type, the first signs of the ASR (gels, expansions and cracks) appear in the concrete in one year or less, depending on the environmental conditions. When this aggregate is mixed with another, whether reactive or not, an expansion pessimum effect can occur. Therefore, when this type of aggregate is to be used, or when it is mixed with another, precautions should be taken to avoid early deterioration in the works.

In previous work, siliceous sandstone from the south of the Province of Corrientes (Argentina) was studied using the accelerated test method (ASTM C 1260) [6].

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The purpose of this study is to check this sandstone performance with respect to the alkalis when it is used as aggregate in concrete manufacture and to compare the results obtained with those of conventional standard tests.

Sandstone outcrop in the area is of two types. One, the oldest, belongs to the Botucatú Formation [7] of Upper Triassic-Upper Jurassic age; it consists of massive beds of reddish, fine-grained to very fine-grained friable quartz-feldspathic to quartzose sandstone that is well sorted and interlayered with basaltic flows. Up to eleven basaltic flows whose thickness ranges from 3 to 80 m have been identified in the Province of Misiones, Argentina (Water Department, 1973). The thickness of these sediments varies widely, ranging from 100 to 450 m. The prevailing texture is clastic with subrounded to irregular quartz grains coated with iron oxides and argillaceous material, which also acts as binding material and is sometimes accompanied by metastable silica (opal and chalcedony) [8]. The aforementioned basalts constitute the Serra Geral Formation [9] of Lower Cretaceous age [10] composed of reddish-brown, greyish and black tholeiitic basalts of variable thickness that make up an area of 800 to 1100 metres.

The other sandstone, of Upper Cretaceous age, from the Yeruá Formation, unconformably overlies basaltic flows [11,12]. It is composed of pink, fine to medium-grained quartzose sandstone with polymictic conglomerate levels containing basalt, quartz and sandstone particles, with horizontal and cross-cutting stratification, which are silicified with abundant siliceous cement. It is correlated with the Guichón Formation of Upper Cretaceous age of the centre-west of Uruguay and with the Baurú Group in the south of Brazil. The sandstone used in this test belongs to these levels.

The Cretaceous–Tertiary transition in the area of study is located between the cities of Curuzú Cuatiá and Mercedes, Argentina. It consists of discontinuous limestone and calcrete outcrops, with fine-grained quartzose sandstone, with almost no matrix or siliceous cement, ferric segregations, limestone and calcretes. The most abundant cement is composed of chalcedony, cryptocrystalline silica and opal (Pay Ubre Formation). The samples studied belong to the Guichón Formation – Baurú Group.

## 2 MATERIALS

The material used in this study comes from a sandstone outcrop located at 10 km of the city of Curuzú Cuatiá (Province of Corrientes, Argentina), and is closed to national route No 119. The thickness is below 5 metres and the base does not crop out. It exhibits weak stratification, conchoidal fracture; it is compact, very well cemented and reddish grey.

Siliceous sandstones similar to the one analysed in this study have been found in the provinces of Corrientes (east-northeast of Mercedes and east and south of Curuzú Cuatiá) and Entre Ríos (Yeruá Port) in Argentina and in Uruguay as well.

The portland cement used in the tests is a OPC 40 containing 0.82% alkali expressed as Na2O equivalent.

The fine aggregate used to make the concrete prism (ASTM C1293) is non-reactive natural sand from the Río de la Plata, consisting of above 90% quartz.

## 3 METHODS

The mineralogical and petrographic study of the rock was performed as specified in ASTM C 295 and was supplemented with thin sections [13].

Dissolved silica was determined as prescribed in ASTM C 289 [14]. The samples were crushed to pass a 600-µm sieve and be retained on a 300-µm sieve. They were stored in a NaOH solution at 80° C for 24 h, then an aliquot was drawn and brought to acid pH. Dissolved silica was determined by gravimetry.

The reactive behaviour was determined by the concrete prism method (ASTM C 1293) [15]. The results were compared with those of the accelerated mortar bar test method (ASTM C 1260) [16] from previous work. The mineralogical characterization and the study of reaction products in the processed concrete and mortars were performed using an Olympus B2-UMA trinocular petrographic microscope and a scanning electron microscope (JEOL JSM 35 CP equipped with EDAX probe).

## 4 RESULTS

### 4.1 Petrography

The rock studied is quartzose sandstone composed mainly of well-sorted, equidimensional, subrounded to irregular quartz particles that range from 120 to 350 μm in size (Figure 1a) and rare basalt, quartzite and sandstone fragments. They are cemented by fibrous cryptocrystalline silica, of low interference colour, with wedge-shaped twins and a very low refraction index attributed to chalcedony, trydimite, opal and cristobalite (Figure 1b). No matrix components have been identified.

### 4.2 Physical and chemical tests

Expansion curves prepared in accordance with the accelerated test method ASTM C1260 are shown in Figure 2. At 5 days expansion values are above 0.100% and at 10 days they exceed 0.200%, which is in agreement with the performance of a fast-reacting aggregate. Cracking on the bar surfaces appeared at 11 days.

Figure 3 shows expansion versus time for the concrete prism test. At 15 days a small amount of gel formed, which increased progressively with time.

The results obtained when the sample was tested in accordance with ASTM C1260 and ASTM C1293 methods and dissolved silica as determined by ASTM C289 are summarized in Table 1. The dissolved silica value is high and is indicative of potentially reactive aggregates when it is compared to the results of previous work [17,18].

### 4.3 Petrography of mortar bars and concrete prisms

The microstructure of mortar bars was examined after ASTM C 1260 testing for 28 days. The texture and composition of the rock cementitious material have been completely altered. Cracks are abundant and affect the lithological components and the mortar.

Examination of the concrete prism reveals that the rock has no cement. Figure 4a shows that sandstone quartz grains are isolated, with no cryptocrystalline silica cement. Figure 1b shows a detail of the diffused aggregate-mortar interface, characterized by irregular, undefined boundaries due to silica leaching and mobility.

### 4.4 SEM / EDS

The microstructure of mortar bars was analysed with the scanning electron microscope.
Figure 5a shows sandstone quartz grains where part of the siliceous cement is lacking due to alkali attack; quartz grains with no cementing material can also be seen. EDS analysis mainly shows Si and O reflections corresponding to sandstone quartz particles with a lower Na and Ca content, which corresponds to siliceous cement (Figure 5b).

## 5 CONCLUSIONS

- Dissolved silica, determined in accordance with ASTM C 289 test method, is high; so a deleterious reaction should be expected.

- Expansion values measured when the accelerated mortar bar (ASTM C 1260) and concrete prism (ASTM C 1293) test methods were used are well above the maximum limits established in the bibliography.
- The reaction development and the maximum expansion values are indicative of potentially reactive sandstone; the reaction kinetics corresponds to fast-reacting aggregates. When environmental conditions (temperature and relative humidity) are favourable, the pathology produced by this aggregate will occur shortly after the concrete works have been built, sometimes in less than a year.
- The results obtained with the three methods used are consistent enough to classify this aggregate as potentially alkali reactive.
- The deleterious performance is attributed to the sandstone cement that consists of chalcedony, cristobalite, opal and cryptocrystalline quartz.
- When this rock is to be used as the sole aggregate or mixed with another, technological studies should be conducted to avoid ASR development and concrete deterioration leading to shortened service life and/or costly repairs that have not been included in the project budget.

## 6 ACKNOWLEDGEMENTS

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Table 1: Average values of mortar bar and concrete prism expansion and dissolved silica

| Expansion %, accelerated method | | Expansion %, concrete prism | | Dissolved silica (mg) |
|---|---|---|---|---|
| 16 days | 28 days | 1 year | 2 years | |
| 0.337 | 0.432 | 0.068 | 0.076 | 225.2 |

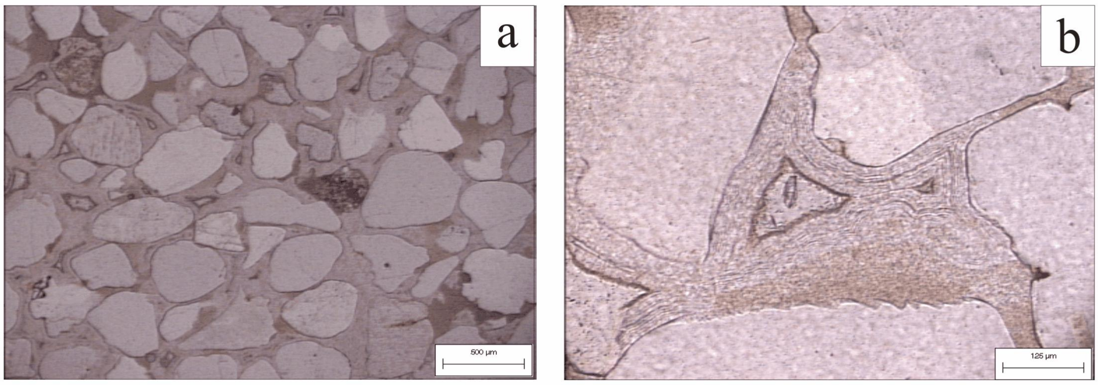


FIGURE 1. a: Sandstone textural characteristics (under parallel light). b. Detail of cryptocrystalline silica cement

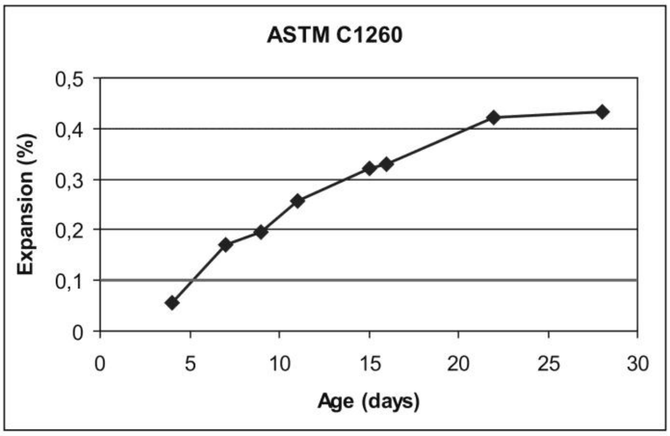


FIGURE 2. Expansion versus time. Mortar bar accelerated test method

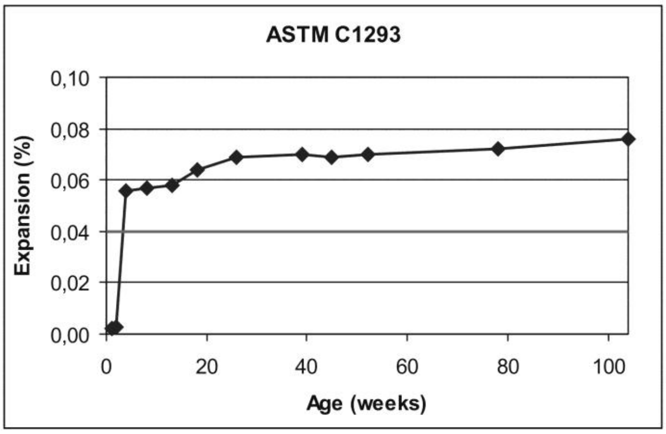


FIGURE 3. Expansion versus time. Concrete prism method

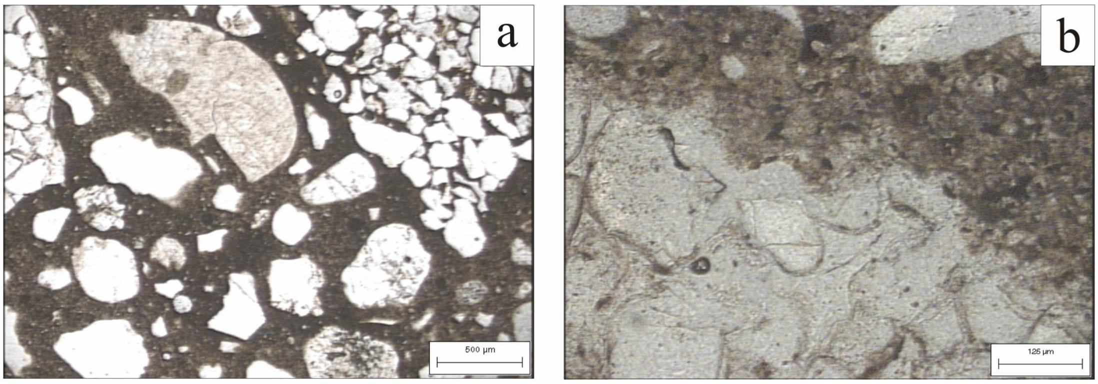


FIGURE 4: Petrographic microscopy on thin sections of the concrete prism. a: Dissolution of the cementing material of sandstone quartz particles. b: Detail of the aggregate-mortar interface

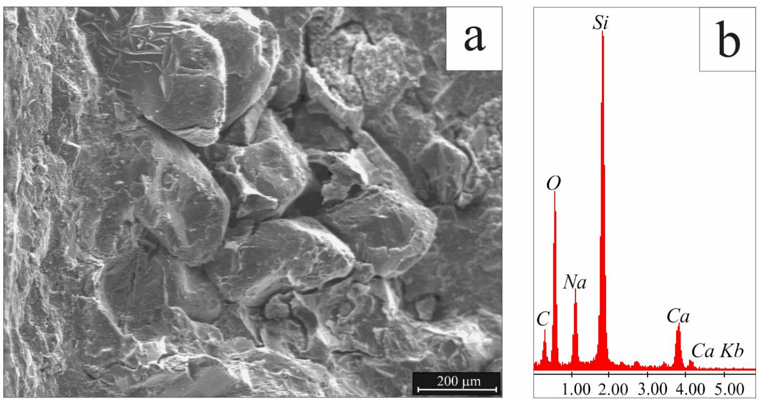


FIGURE 5: a: Sandstone quartz grains with no cementing material. b: chemical composition determined by EDS