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# Alkali-Silica Reactivity Of Three River Basin (Chenab, Satluj And Beas) - An Overview

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*Abstract*— **Alkali-silica reaction is one of the most recognized deleterious phenomenon in concrete that results in excessive expansion, cracks, loss in mechanical properties and serviceability problems. Aggregates constitute about three-quarter of the volume of concrete, and therefore their physical, mechanical and chemical properties need to be correctly assessed before their use in concrete. Aggregate component in concrete define its thermal, elastic properties and mineralogical composition which influences the durability of concrete. This paper presents research on the influence of strain quartz percentage in aggregates for the occurrence of potentially deleterious alkali-silica reaction in concrete. The aggregates susceptible to ASR were evaluated using petrographic analysis, aggregate mineralogy, chemical method of ASTM C 289 and the standard methods of ASTM C 1260 and ASTM C 1293. Aggregate classifications into innocuous and reactive based on the stated mineralogy tests and the potential expansion limits based on the standard test methods and their modifications were compared. The study demonstrated that none of the single method is an ideal approach to evaluate the alkali-silica reactivity of an aggregate in a better way and a suitable combination of various methods can be utilized to better predict the potential ASR of an aggregate.**

*Index Terms*— **Alkali-Silica Reaction, Aggregate Mineralogy, Alkalis, Moisture, Petrographic Analysis.**

## I. INTRODUCTION

Alkali-aggregate reaction has two forms: alkali-silica reaction (ASR) and alkali-carbonate reaction (ACR). Alkali-silica reaction (ASR) is a reaction that takes place between the reactive silica contained in aggregates and the alkalis in the cement paste. For the reaction to take place in concrete, three conditions must exist: high pH, moisture, and reactive silica. Various types of silica present in aggregates react with the hydroxyl ions present in the pore solution in concrete. The silica, now in solution, reacts with the sodium (Na+) and potassium (K+) alkalis to form a volumetrically unstable alkali silica gel. Once formed, the gel starts imbibing water and swelling to a greater volume than that of the reacted materials. Water absorbed by the gel can be water not used in the hydration reaction of the cement, free water from rain, melted snow, tides, rivers, or water condensed from air moisture (ACI 221, 1998).

Alkali carbonate reaction (ACR) is the reaction between the cement hydroxides and certain dolomitic limestone aggregates, which can also result in deleterious expansion. This problem is relatively less prevalent in India and is not specifically addressed here.

In general, the reaction can be viewed as a two-step process (Farny, 1996):

***Step 1:***

Silica + alkali ⟶ alkali-silica gel (sodium silicate)

$SiO_2 + 2NaOH + H_2O \longrightarrow Na_2SiO_3.2H_2O$ (2KOH can replace 2NaOH)

***Step 2***

Gel reaction product + water ⟶ expansion

Since the gel is restrained by the surrounding mortar, an osmotic pressure is generated by the swelling. Once that pressure is larger than the tensile strength of the concrete, cracks occur, leading to additional water migration or absorption and additional gel swelling (ACI 221, 1998).

## II. PRESENT STUDY

The overall objective of the study was to closely examine the alkali-silica reaction expansion potential in portland cement concrete containing different aggregate sources in the river basins in Himachal Pradesh, India. Fourteen aggregate sources were selected from three river basins (Chenab, Satluj and Beas) at various locations of Himachal Pradesh as shown in Fig.1. Ten coarse aggregate samples were obtained from rock quarry and the remaining four from river bed material (RBM). Both were analyzed for ASR and their reactivity was determined from different tests that were carried out on the coarse aggregate samples as per existing test methods and results were evaluated.

Petrographic analyses of all these rock types were carried out to find the strained quartz percentage, undulatory extinction angle and its mineralogical composition. Three samples for each fourteen rock type were studied and respective minimum and maximum values of their constituents are presented in Table 2

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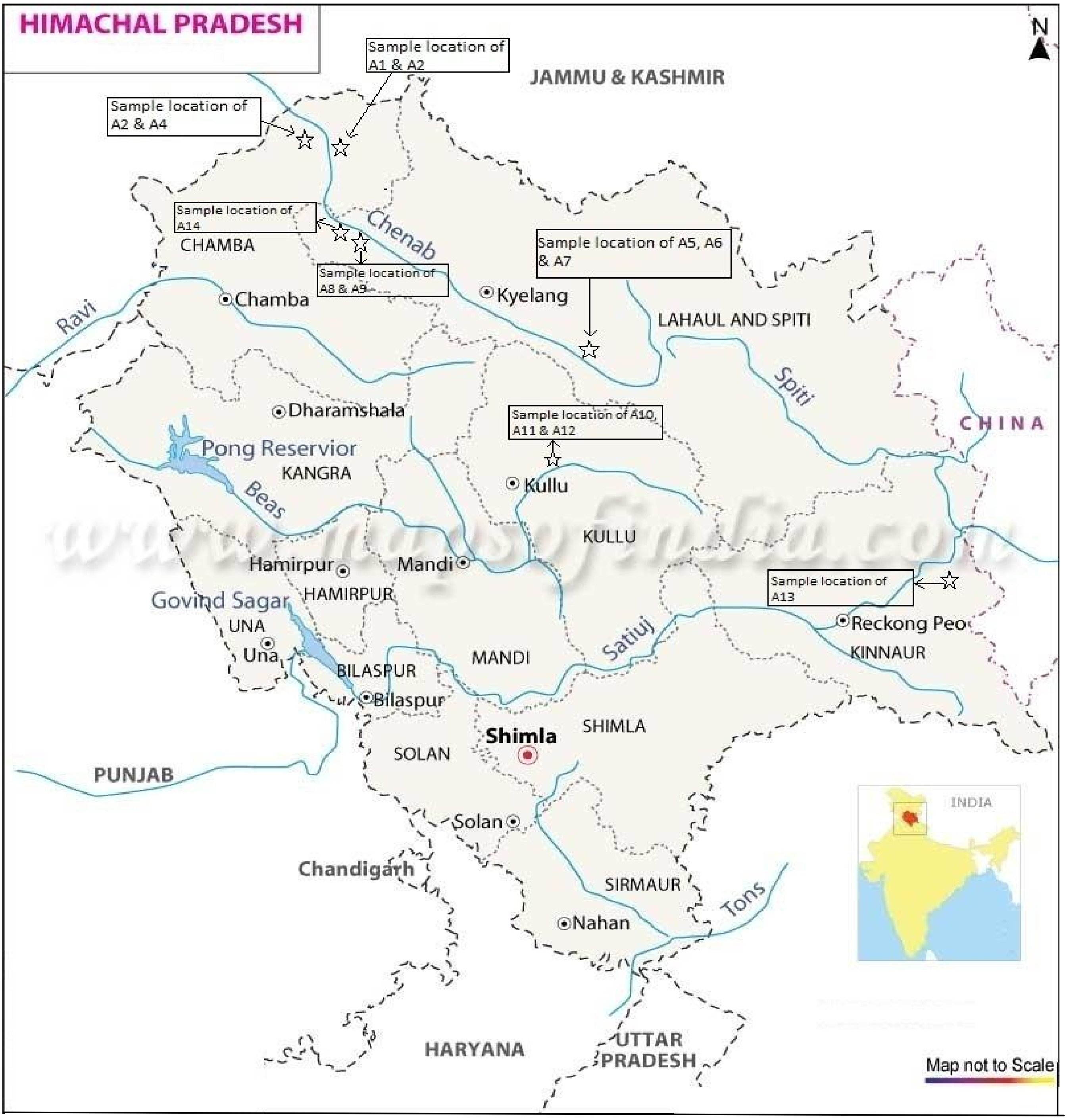

Table 1: Rock type and sources

| ID | Rock Type | River Basin | Type of Source | Location |
|---|---|---|---|---|
| A1 | Granite Biotite Schist | Chenab river basin | Rock Quarry | Himachal Pradesh |
| A2 | Granite Biotite Gneiss | Chenab river basin | Rock Quarry | Himachal Pradesh |
| A3 | Calcareous Quartzite | Chenab river basin | Rock Quarry | Himachal Pradesh |
| A4 | Micaceous Quartzite | Chenab river basin | Rock Quarry | Himachal Pradesh |
| A5 | Gneiss | Chenab river basin | Rock Quarry | Himachal Pradesh |
| A6 | Feldspathic Schist | Chenab river basin | RBM | Himachal Pradesh |
| A7 | Biotite Schist | Chenab river basin | RBM | Himachal Pradesh |
| A8 | Meta Siltstone | Chenab river basin | Rock Quarry | Himachal Pradesh |
| A9 | Quartzite | Chenab river basin | Rock Quarry | Himachal Pradesh |
| A10 | Garnet Biotite-Schist | Beas Basin | RBM | Himachal Pradesh |
| A11 | Dolomitic Limestone | Beas Basin | Rock | Himachal Pradesh |
| A12 | Sandstone | Beas Basin | RBM | Himachal Pradesh |
| A13 | Granite Gneiss | Satluj river basin | Rock | Himachal Pradesh |
| A14 | Quartzitic Phyllite | Chenab river basin | Rock Quarry | Himachal Pradesh |

**Table 2: Mineralogical composition of aggregate samples**

| ID | Rock Type | Strain Quartz in % | UEA in degree | Quartz in % | Feldspar in % | Biotite in % | Muscovite in % | Iron Oxide in % | Dolomite in % |
|---|---|---|---|---|---|---|---|---|---|
| A1 | Granite Biotite Schist | 35-45 | 25-35 | 30-38 | 25-31 | 14-20 | 4-9 | 1-3 | - |
| A2 | Granite Biotite Gneiss | 30-45 | 9-27 | 39-53 | 21-31 | 8-13 | 2-6 | 1-3 | - |
| A3 | Calcareous Quartzite | 30-45 | 9-17 | 44-59 | 10-18 | 4-7 | 9-16 | 2-4 | - |
| A4 | Micaceous Quartzite | 30-32 | 10-15 | 50-55 | 13-16 | 5-6 | 8-9 | 3-4 | - |
| A5 | Gneiss | 80-86 | 26-35 | 35-40 | 22-30 | 5-18 | 2-13 | <2 | - |
| A6 | Feldspathic Schist | 80-85 | 23-25 | 44-49 | 33-38 | 6-11 | 2-3 | - | - |
| A7 | Biotite Schist | 81-86 | 31-36 | 35-40 | 25-30 | 17-20 | 3-5 | - | - |
| A8 | Meta Siltstone | 15-22 | 16-22 | 40-49 | 24-31 | 7-12 | 4-7 | 2-4 | 0 |
| A9 | Quartzite | 22-26 | 29-33 | 73-78 | 6-9 | <2 | 2-3 | 2-3 | 0 |
| A10 | Garnet Biotite-Schist | 45-50 | 18-22 | 40-50 | 11-27 | 18-21 | 1-8 | 5-10 | - |
| A11 | Dolomitic Limestone | 30-40 | 16-18 | 8-10 | 0 | 0 | 0 | 10 | 15-20 |
| A12 | Sandstone | 45-51 | 19-23 | 70-71 | 8-18 | 5-7 | 1-5 | 1-6 | - |
| A13 | Granite Gneiss | 18-22 | 16-21 | 56-64 | 12-20 | 8-12 | 8-12 | 2-4 | - |
| A14 | Quartzitic Phyllite | 32-45 | 17-27 | 36-54 | 12-27 | 3-8 | 3-12 | 2-3 | - |

Chemical method test as per ASTM C 289 was then carried out on all these rock types for quick understanding of the reactiveness of the aggregate. Out of fourteen samples, eleven were found innocuous and three deleterious as per Figure - 2. The details are presented in the Table -3

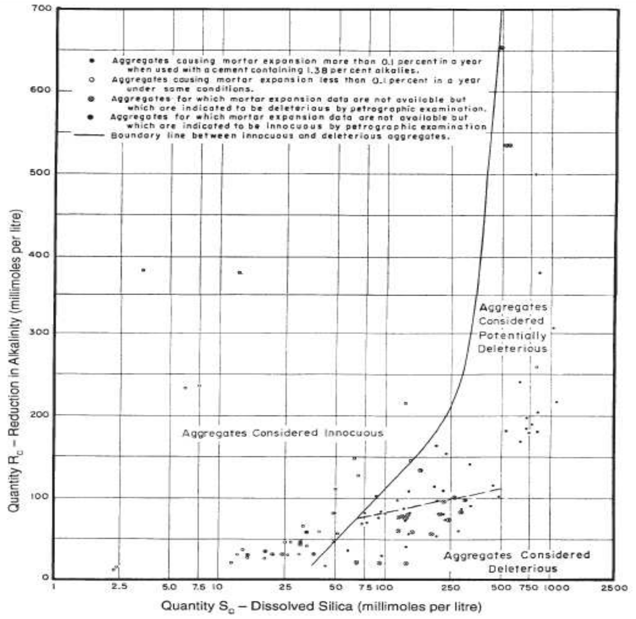

**Fig. 2:** Illustration of division between Innocuous and Deleterious aggregates on basis of reduction in Alkalinity test

**Table 3: Silica dissolved and reduction in alkalinity of rock samples**

| **ID** | **Rock Type** | **Silica dissolved (Sc) Milli moles/litre** | **Reduction in alkalinity (Rc) Milli moles/litre** | **Reactivity** |
|---|---|---|---|---|
| A1 | Granite Biotite Schist | 4.40 | 95.33 | Innocuous |
| A2 | Granite Biotite Gneiss | 10.60 | 94.67 | Innocuous |
| A3 | Calcareous Quartzite | 15.00 | 52.50 | Innocuous |
| A4 | Micaceous Quartzite | 26.45 | 44.66 | Innocuous |
| A5 | Gneiss | 10.50 | 95.00 | Innocuous |
| A6 | Feldspathic Schist | 10.65 | 198.00 | Innocuous |
| A7 | Biotite Schist | 6.50 | 140.00 | Innocuous |
| A8 | Meta Siltstone | 30.00 | 103.55 | Innocuous |
| A9 | Quartzite | 22.10 | 91.50 | Innocuous |
| A10 | Garnet Biotite-Schist | 80.00 | 35.00 | Deleterious |
| A11 | Dolomitic Limestone | 140.00 | 37.00 | Deleterious |
| A12 | Sandstone | 65.00 | 18.00 | Deleterious |
| A13 | Granite Gneiss | 10.70 | 72.50 | Innocuous |
| A14 | Quartzitic Phyllite | 15.80 | 435.33 | Innocuous |

After petrographic and chemical method investigation, all rock types were investigated by adopting test procedure as per ASTM C1260 because of the presence of reactive strain quartz. This method is generally prevalent and preferred by the construction industries because of its rapidity in determining its potential to undergo alkali aggregate reaction within a months' time which is very helpful in preliminary investigation for rock selection of any project. The test results are presented in Table 4 and the same plotted in Fig 3

**Table 4: Results of 16 days expansion of rock samples**

| ID | Rock Type | ASTM 1260 % expansion at 16 days after casting | Reactivity |
|---|---|---|---|
| A1 | Granite Biotite Schist | 0.023 | Innocuous |
| A2 | Granite Biotite Gneiss | 0.027 | Innocuous |
| A3 | Calcareous Quartzite | 0.019 | Innocuous |
| A4 | Micaceous Quartzite | 0.016 | Innocuous |
| A5 | Gneiss | 0.053 | Innocuous |
| A6 | Feldspathic Schist | 0.118 | Innocuous/Deleterious |
| A7 | Biotite Schist | 0.125 | Innocuous/Deleterious |
| A8 | Meta Siltstone | 0.029 | Innocuous |
| A9 | Quartzite | 0.040 | Innocuous |
| A10 | Garnet Biotite-Schist | 0.204 | Deleterious |
| A11 | Dolomitic Limestone | 0.130 | Innocuous/Deleterious |
| A12 | Sandstone | 0.210 | Deleterious |
| A13 | Granite Gneiss | 0.072 | Innocuous |
| A14 | Quartzitic Phyllite | 0.039 | Innocuous |

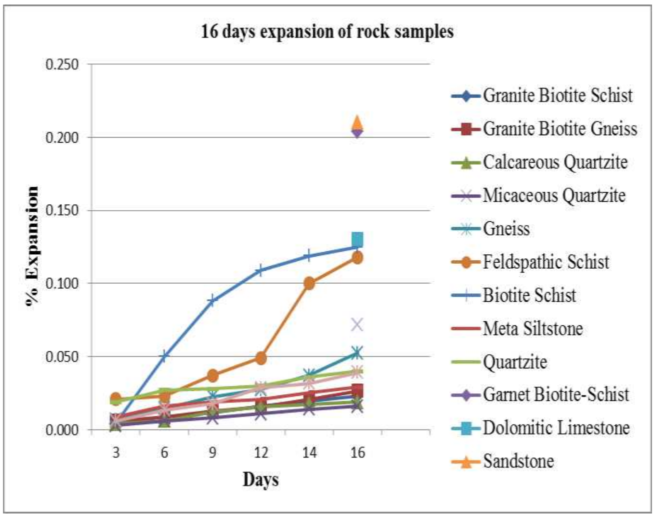

**Fig. 3: 16 days expansion of rock samples**

A graph is then plotted to understand the relation between % strain quartz (weighted value or by weight of highly strain quartz) and % expansion of rock type and is as presented in Fig. 4

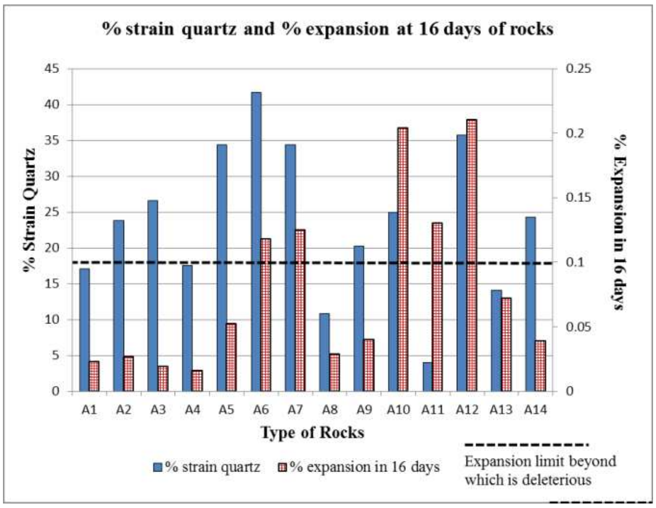

**Fig. 4: % strain quartz and % expansion at 16 days of rocks**

There is a clear trend from fig. 3 that with increase of % strain quartz in rock type, there is an increase of expansion. Rock type (A1, A2, A3, A4, A5, A8, A9, A13 & A14) were found to be innocuous, (A6, A7 & A11) were found to be innocuous and deleterious and (A10 & A12) were found to be potentially deleterious. Even though rock type A11 has low percentage of strain quartz yet increase of expansion is more, this could be due to dolomitic type of rock or presence of any other potentially deleterious reactive minerals other than strained quartz.

Further tests of Rock type A10 & A11 were carried out by adopting test procedure as per ASTM C1293 and the results are as presented in Table 5.

**Table 5: One year expansion of rock samples**

| ID | Rock Type | ASTM 1293 Prism Bar test results | Reactivity |
|---|---|---|---|
| A10 | Garnet Biotite-Schist | 0.0508 | Deleterious |
| A11 | Dolomitic Limestone | 0.0340 | Innocuous |

## III. CONCLUSION

The following conclusions were generated on the use of ASTM C 1260 and ASTM C 1293 for predicting the potential reactivity of aggregates:

- ASTM C 1260 is too severe for some rock type (A11) indicating that they are reactive while the rock type passes ASTM C 1293.
- ASTM C 1260 should not be solely used to determine the potential reactivity of rock type but should be confirmed by ASTM C 1293 in case the rock type is found to be reactive.
- Since A11 rock type is of Dolomite type, so ASTM C 586 & ASTM C 1105 should be used to determine the potential reactivity.

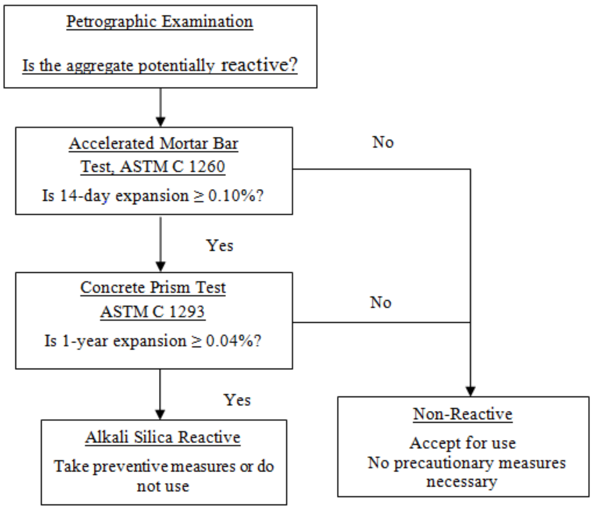

**Fig. 5: Sequence of Laboratory tests for evaluating ASR**

The flowchart in Fig. 5 shows the general sequence of testing and decisions that should be made when evaluating a source of aggregate for potential ASRof aggregate for potential ASR

In view of the above aggregate samples must be tested with different test procedures for arriving at conclusive judgement of the potential reactivity of the aggregate. The use of supplementary cementitious materials must always be suggested, what so ever may be the percentage of strain quartz and undulatory extinction angle. This will not only help in mitigating the ASR, but also some more advantages like less heat of hydration in case of massive structures, formation of more C-S-H gel because of pozzolanic activity, pore refinement, eco-friendly and in totality improves the durability of the concrete produced.

## ACKNOWLEDGMENT

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## REFERENCES

[1] ASTM C 227-03: Standard test method for potential Reactivity of cement-aggregate combination (Mortar-Bar Method)
[2] ASTM C 289: Test methods for potential Alkali-Silica Reactivity of aggregate (Chemical Method)
[3] ASTM C 295: Guide for petrographic Examination of aggregates for concrete
[4] ASTM C 1260 : Standard Test Method for potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
[5] ASTM C 1293: Standard Test method for Determination of length change of concrete due to alkali silica reaction
[6] ASTM C 1567 Standard test method for potential alkali reactivity of aggregates (Mortar bar method)
[7] Highway Research Program, National Research Council, Washington,DC
[8] Diagnosis and control of alkali aggregate reactions in concrete, James A, Farny and Steven H. Kosmatka, Concrete Information, PCA
[9] The alkali silica reaction in concrete, R.N.Swamy
[10] ACI221.1R-98, Report on Alkali-aggregate Reactivity
[11] Alkali-aggregate reaction in concrete dams, ICOLD Bulletin 79

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