
Standard Practice for

**Determining the Reactivity of
Concrete Aggregates and Selecting
Appropriate Measures for
Preventing Deleterious Expansion
in New Concrete Construction**

AASHTO Designation: R 80-17¹

Technical Subcommittee: 3c, Hardened Concrete

Release: Group 1 (April)



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Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction

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1. SCOPE

- 1.1. This practice describes approaches for identifying potentially deleteriously reactive aggregates and selecting appropriate preventive measures to minimize the risk of expansion when such aggregates are used in concrete. Both alkali-silica reactive and alkali-carbonate reactive aggregates are covered. Preventive measures for alkali-silica reactive aggregates include avoiding the reactive aggregate, limiting the alkali content of the concrete, using blended cement, using supplementary cementitious materials, using lithium nitrate as an admixture, or a combination of these measures. Preventive measures for alkali-carbonate reactive rocks are limited to avoiding the reactive aggregate.
- 1.2. The values stated in SI units are the preferred standard.
- 1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
- M 240M/M 240, Blended Hydraulic Cement
 - M 295, Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
 - M 302, Slag Cement for Use in Concrete and Mortars
 - M 307, Silica Fume Used in Cementitious Mixtures
 - T 303, Accelerated Detection of Potentially Deleterious Expansion of Mortar Bars Due to Alkali-Silica Reaction
- 2.2. *ASTM Standards:*
- C295/C295M, Standard Guide for Petrographic Examination of Aggregates for Concrete
 - C586, Standard Test Method for Potential Alkali Reactivity of Carbonate Rocks as Concrete Aggregates (Rock-Cylinder Method)

- C856, Standard Practice for Petrographic Examination of Hardened Concrete
- C1105, Standard Test Method for Length Change of Concrete Due to Alkali-Carbonate Rock Reaction
- C1157/C1157M, Standard Performance Specification for Hydraulic Cement
- C1260, Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
- C1293, Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction
- C1567, Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)

2.3. *Canadian Standards:*

- CSA A23.2-14A, Potential Expansivity of Aggregates (Procedure for Length Change Due to Alkali-Aggregate Reaction in Concrete Prisms)
- CSA A23.2-26A, Determination of Potential Alkali-Carbonate Reactivity of Quarried Carbonate Rocks by Chemical Composition

2.4. *RILEM Recommendation:*

- RILEM TC 191-ARP, Alkali-Reactivity and Prevention—Assessment, Specification, and Diagnosis of Alkali-Reactivity

3. TERMINOLOGY

- 3.1. *accelerated mortar-bar test (AMBT)*—test method used to determine aggregate reactivity (AASHTO T 303) or to evaluate the effectiveness of measures to prevent deleterious expansion when reactive aggregates are used (ASTM C1567).
- 3.2. *alkali-aggregate reaction (AAR)*—chemical reaction in either mortar or concrete between alkalis (sodium and potassium) present in the concrete pore solution and certain constituents of some aggregates; under certain conditions, deleterious expansion of concrete or mortar may result. Two types of AAR are considered in this standard practice; these are alkali-carbonate reaction (ACR) and alkali-silica reaction (ASR).
- 3.3. *alkali-carbonate reaction (ACR)*—the reaction between the alkalis (sodium and potassium) present in the concrete pore solution and certain carbonate rocks, particularly argillaceous calcitic dolomite and argillaceous dolomitic limestone, present in some aggregates; the products of the reaction may cause deleterious expansion and cracking of concrete.
- 3.4. *alkali-silica reaction (ASR)*—the reaction between the alkalis (sodium and potassium) present in the concrete pore solution and certain siliceous rocks or minerals, such as opaline chert, strained quartz, and acidic volcanic glass, present in significant quantities in some aggregates; the products of the reaction may cause deleterious expansion and cracking of concrete.
- 3.5. *class of structure*—in this guideline, structures are classified on the basis of the severity of the consequences should ASR occur.
- 3.6. *concrete prism test (CPT)*—test method (ASTM C1293) used to determine aggregate reactivity or to evaluate the effectiveness of measures to prevent deleterious expansion when reactive aggregates are used. Another version of this test, ASTM C1105, can be used with a limited alkali content to determine the potential for alkali-carbonate reactivity.

- 3.7. *deleterious expansion*—an increase in volume that is sufficient to cause cracking of the concrete or result in other problems (e.g., misalignment of adjacent components, closing of joints, etc.).
- 3.8. *deleteriously reactive*—aggregates that undergo chemical reactions in concrete that subsequently result in deleterious expansion of the concrete.
- 3.9. *equivalent alkali*, Na_2Oe —calculated from the sodium (Na_2O) and potassium oxide (K_2O) as follows: $\text{Na}_2\text{Oe} = \text{Na}_2\text{O} + 0.658 \times \text{K}_2\text{O}$.
- 3.10. *nondeleteriously reactive*—aggregates with no reactive constituents or minor amounts of reactive constituents that may exhibit some small amount of reaction without producing significant damage to the concrete.
- 3.11. *preventive measures*—strategies for suppressing damaging expansion due to alkali–aggregate reaction (AAR).
- 3.12. *supplementary cementitious material (SCM)*—cementitious materials other than portland cement (i.e., pozzolans and slag).

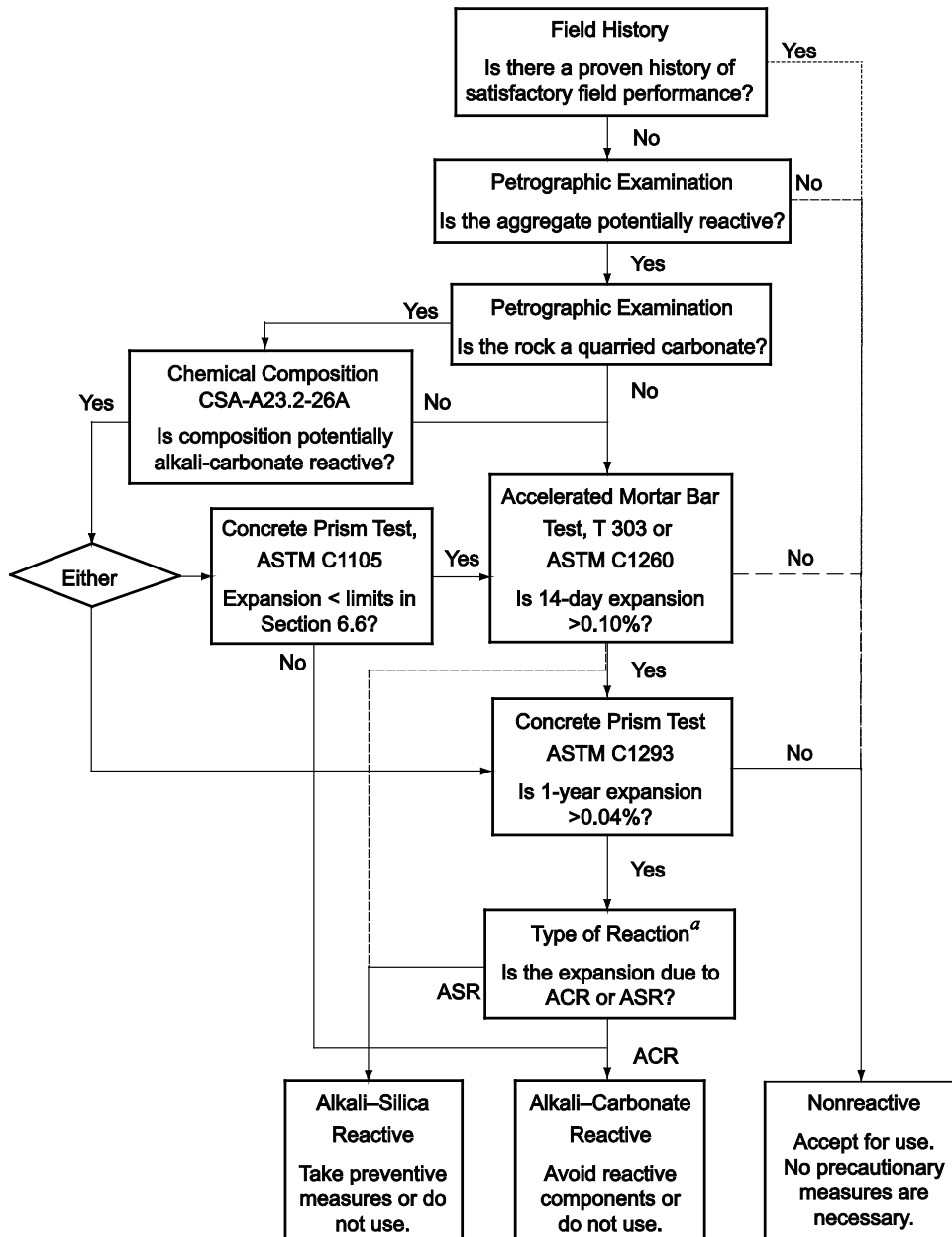
4. SIGNIFICANCE AND USE

- 4.1. This practice describes a procedure for evaluating aggregate reactivity and determining measures to prevent deleterious expansion due to alkali–aggregate reaction (AAR).
- 4.2. Following this practice will not completely eliminate the possibility of deleterious expansion occurring in new construction; rather, the practice provides various approaches for minimizing the risk of AAR to a level acceptable to the owner.
- 4.3. Aggregate reactivity is determined on the basis of one or more of the following: field performance, petrographic examination, or the expansion testing of mortars or concrete, or both.
- 4.4. If the aggregate is deemed to be nondeleteriously reactive, it can be accepted for use in concrete with no further consideration of preventive measures (assuming that the physical properties of the aggregate render it suitable for use).
- 4.5. If the aggregate is found to be deleteriously reactive, it must then be determined whether the reaction is of the alkali–carbonate or alkali–silica type.
- 4.6. If the aggregate is alkali–silica reactive, the aggregate may be either rejected for use or accepted with an appropriate preventive measure. There are a number of options for minimizing the risk of expansion with alkali–silica reactive rocks. This practice allows for preventive measures to be evaluated on the basis of performance testing or to be selected prescriptively from a list of options based on previous experience. The level of prevention required is a function of the reactivity of the aggregate, the class of structure, the nature of the exposure conditions, the availability of alkali in the system, the type of material used for prevention, and the level of risk the owner is willing to accept.
- 4.7. If the aggregate is alkali–carbonate reactive, the aggregate must be rejected for use. There are no proven measures for effectively preventing damaging expansion with alkali–carbonate reactive rocks, and such materials should not be used in concrete without selective quarrying or processing to limit the reactive components to acceptable levels.
- 4.8. In the approach outlined here, the level of testing varies depending on the level of risk that is acceptable to the owner. For example, in regions where occurrences of AAR are rare or where the

aggregate sources in use have a long history of good field performance, it may be reasonable to continue to rely on the previous field history without subjecting the aggregates to laboratory tests. However, in regions where AAR problems are known and where the reactivity of aggregates is known to vary from source to source, it may be necessary to implement a rigorous testing regime to establish the potential aggregate reactivity and evaluate preventive measures.

5. GENERAL APPROACH

- 5.1. The flow chart in Figure 1 shows the sequence of testing and decisions that has to be made when evaluating a source of aggregate for potential AAR. It is recommended that the following sequence of testing is followed to determine aggregate reactivity: consideration of field performance history, petrographic examination, accelerated mortar-bar testing, and concrete prism testing. If the rock is a quarried carbonate, additional tests are required to determine the potential for alkali-carbonate reaction (as shown in Figure 1). Some agencies may adopt one or more of these test procedures, depending on prior experience with AAR and the acceptable level of risk of AAR in new construction.



^a The type of reaction needs to be determined only after the concrete prism test if the aggregate being tested is a quarried carbonate that has been identified as being potentially alkali-carbonate reactive by chemical composition in accordance with test method CSA A23.2-26A. The solid lines show the preferred approach. However, some agencies may want to reduce the amount of testing and accept a higher level of risk, and this can be achieved by following the direction of the dashed lines.

Figure 1—Sequence of Laboratory Tests for Evaluating Aggregate Reactivity

5.2. Appropriate preventive measures can be selected either by performance testing using the accelerated mortar-bar test or concrete prism test, or by using prescribed measures that have been developed based on previous experience and published research data. The level of prevention prescribed is a function of the class of the structure, the reactivity of the aggregate, the alkali content of the portland cement, the composition of the material used for prevention, the exposure conditions, and the level of risk the owner is willing to accept.

Note 1—If desired, performance testing can be conducted on the aggregate with preventive measures, without first establishing aggregate reactivity.

6. DETERMINING AGGREGATE REACTIVITY

6.1. *Field Performance History:*

6.1.1. The long-term field performance history of an aggregate can be established by consulting the available documentation (e.g., specifications and construction files) and conducting a survey of existing structures that were constructed using the same or similar (i.e., from the same geological environment) aggregate source. As many structures as practical should be included in the survey, and these structures should, where possible, represent different types of construction (pavements, sidewalks, curb and gutter, elements of bridges, barrier walls, and even nontransportation structures). The following information should be collected for each structure: (1) *age*—structures should be at least 10 years old and preferably more than 15 years old as deleterious expansion due to AAR can take more than 10 years to develop; (2) *cement content and alkali content* of the cement used during construction; (3) use and type of *supplementary cementitious materials* during construction; (4) *exposure condition*—availability of moisture, use of deicing chemicals; and (5) presence and type of *symptoms of distress* due to AAR or other causes.

6.1.2. Cores should be taken from a representative number of these structures and petrographic examinations conducted in accordance with ASTM C856 to establish the following: (1) the presence or not of evidence of deleterious expansion due to AAR, (2) the aggregate used in the structures surveyed is close in mineralogical composition to that of the aggregate currently being produced, and (3) the presence and an estimate of the quantity of supplementary cementitious materials.

6.1.3. If the results of the field survey indicate that the aggregate is nondeleteriously reactive, the aggregate may be used in new construction provided that the new concrete is not produced with a higher alkali loading, a lower amount of or different supplementary cementitious materials, or more aggressive exposure condition than the structures included in the survey.

6.1.4. If field performance indicates that an aggregate source is deleteriously reactive, laboratory expansion testing is required to determine the level of aggregate reactivity and to evaluate prevention measures.

Note 2—There is a certain level of risk associated with accepting aggregates solely on the basis of field performance because of difficulties in establishing unequivocally that the materials and proportions used are similar to those to be used in new construction. For example, petrographic examination can estimate only the quantity of pozzolans and slag to the nearest 10 percent or so and is not able to determine the composition of the material (e.g., Class F versus Class C fly ash). The presence of very finely divided pozzolans (silica fume) cannot be detected using a petrographic examination.

6.2. *Petrographic Examination:*

6.2.1. Petrographic examination of aggregates should be conducted in accordance with ASTM C295/ C295M. Petrography can reveal useful information about the composition of an aggregate, including the identification and approximate quantification of reactive minerals.

6.2.2. Petrography may be used to classify an aggregate as potentially reactive, but expansion testing is required to determine the extent of potential reactivity and appropriate levels of prevention.

- 6.2.3. Quarried carbonate rocks should be tested to determine the chemical composition and the potential for alkali-carbonate reaction in accordance with Section 6.3.

Note 3—Aggregates may be accepted as nondeleteriously reactive solely on the basis of petrography but there is certain level of risk associated with such a decision, as some reactive phases may not be routinely detected by optical microscopy (e.g., finely dispersed cryptocrystalline silica found in some siliceous limestone).

6.3. *Determination of Potential Alkali-Carbonate Reactive Rocks by Chemical Composition:*

- 6.3.1. If the aggregate being assessed is a quarried carbonate rock, the potential for alkali-carbonate reaction may be assessed on the basis of its chemical composition using the test method CSA A23.2-26A. This test involves the determination of the lime (CaO), magnesia (MgO), and alumina (Al₂O₃) content of the rock and determining where the composition of the rock falls on a plot of CaO/MgO ratio versus the Al₂O₃ content as shown in Figure 2.
- 6.3.2. If the composition falls in one of the two ranges identified as “aggregates considered nonexpansive” in Figure 2, the aggregate is not potentially alkali-carbonate reactive and it should be tested to determine the potential for alkali-silica reaction using the accelerated mortar-bar test (Section 6.4) or the concrete prism test (Section 6.5), or both.
- 6.3.3. If the composition falls in the range of “aggregates considered potentially expansive,” the aggregate is potentially alkali-carbonate reactive and must be evaluated further. There are two options for further testing. One option is to test the aggregate in the concrete prism test, ASTM C1293 (see Section 6.5), to simultaneously determine the potential for alkali-carbonate and alkali-silica reactivity. After the test, the prisms are examined by petrography to determine the role played by the alkali-carbonate reaction (see Section 6.5.5). The second option is to test using the concrete prism test, ASTM C1105, with a reduced alkali loading to determine the potential for alkali-carbonate reaction only (see Section 6.6). If the aggregate passes the expansion criteria in Section 6.6, it is considered not to be alkali-carbonate reactive and can be tested in the same manner as aggregates with a composition that falls in the two ranges identified as “aggregate considered nonexpansive” in Figure 2 (see Section 6.3.2).