Designation: C1778 – 23

Standard Guide for Reducing the Risk of Deleterious Alkali-Aggregate Reaction in Concrete[1]

This standard is issued under the fixed designation C1778; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This guide provides guidance on how to address the potential for deleterious alkali aggregate reaction (AAR) in concrete construction. This guide addresses the process of identifying both potentially alkali-silica reactive (ASR) and alkali-carbonate reactive (ACR) aggregates through standardized testing procedures and the selection of mitigation options to minimize the risk of expansion when ASR aggregates are used in concrete construction. Mitigation methods for ASR aggregates are selected using either prescriptive or performance-based alternatives. Preventive measures for ACR aggregates are limited to avoidance of use. Because the potential for deleterious reactions depends not only on the concrete mixture but also the in-service exposure, guidance is provided on the type of structures and exposure environments where AAR may be of concern.

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C33/C33M Specification for Concrete Aggregates
C114 Test Methods for Chemical Analysis of Hydraulic Cement
C125 Terminology Relating to Concrete and Concrete Aggregates
C150/C150M Specification for Portland Cement
C219 Terminology Relating to Hydraulic and Other Inorganic Cements
C294 Descriptive Nomenclature for Constituents of Concrete Aggregates
C295/C295M Guide for Petrographic Examination of Aggregates for Concrete
C311/C311M Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete
C586 Test Method for Potential Alkali Reactivity of Carbonate Rocks as Concrete Aggregates (Rock-Cylinder Method)
C595/C595M Specification for Blended Hydraulic Cements
C618 Specification for Coal Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
C823/C823M Practice for Examination and Sampling of Hardened Concrete in Constructions
C856 Practice for Petrographic Examination of Hardened Concrete
C989/C989M Specification for Slag Cement for Use in Concrete and Mortars
C1105 Test Method for Length Change of Concrete Due to Alkali-Carbonate Rock Reaction
C1157/C1157M Performance Specification for Hydraulic Cement
C1240 Specification for Silica Fume Used in Cementitious Mixtures
C1260 Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

[1] This guide is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.50 on Aggregate Reactions in Concrete.

Current edition approved Dec. 1, 2023. Published January 2024. Originally approved in 2014. Last previous edition approved in 2022 as C1778 – 22. DOI: 10.1520/C1778-23.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard

C1293/C1293M Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction
C1567 Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
C1866 Specification for Ground-Glass Pozzolan for Use in Concrete

2.2 *ACI Standard:*[3]
ACI 318 Building Code Requirements for Structural Concrete and Commentary

2.3 *AASHTO Standard:*
AASHTO R 80 Standard Practice for Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction[4]

2.4 *CSA Standards:*[5]
A23.2-26A Determination of Potential Alkali-Carbonate Reactivity of Quarried Carbonate Rocks by Chemical Composition
A23.2-27A Standard Practice to Identify Degree of Alkali-Aggregate Reactivity of Aggregates and to Identify Measures to Avoid Deleterious Expansion in Concrete
A23.2-28A Standard Practice for Laboratory Testing to Demonstrate the Effectiveness of Supplementary Cementing Materials and Lithium-Based Admixtures to Prevent Alkali-Silica Reaction in Concrete

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this Guide, refer to Terminology C125, Terminology C219, and Descriptive Nomenclature C294.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *alkali content, Na_2Oeq, n*—value in percent determined by reporting sodium and potassium oxides, determined using procedures for total alkalies in Test Methods C114, of cement or supplementary cementitious material, using the following formula:

$$Na_2Oeq = \%Na_2O + 0.658 \times \%K_2O$$

3.2.2 *alkali loading, n*—amount of alkalies contributed by the cement in a concrete mixture, expressed in kg/m^3 or lb/yd^3 and calculated by multiplying the cement content of the concrete in kg/m^3 or lb/yd^3 by the alkali content of the portland cement, or the portland cement and limestone portion of a blended cement, divided by 100.

3.2.2.1 *Discussion*—Alkali loading is abbreviated as KGA [LBA]. In concrete that includes supplementary cementitious materials; only the alkali content of the cement fraction of the cementitious materials is included in the calculation of alkali loading. For example, in a concrete containing 350 kg/m^3 [590 lb/yd^3] of cementitious materials consisting of 75 % portland cement, 20 % slag, and 5 % silica fume, and where the alkali content of the portland cement is 0.89 % Na_2Oeq, the alkali loading of the concrete is calculated as follows:

$$KGA = 350(75/100)(0.89/100) = 2.3\ kg/m^3$$
$$[LBA = 590\ (75/100)(0.89/100) = 3.9\ lb/yd^3]$$

In a concrete containing 355 kg/m^3 [600 lb/yd^3] of Type IS(25) blended cement, with a base portland cement equivalent alkali content of 0.73 %, the alkali loading of the concrete is calculated as follows:

$$KGA = 355(75/100)(0.73/100) = 1.9\ kg/m^3$$
$$[LBA = 600\ (75/100)(0.73/100) = 3.3\ lb/yd^3]$$

In a concrete containing 350 kg/m^3 [590 lb/yd^3] of Type IL(10) portland-limestone cement, with an equivalent alkali content of the finished cement of 0.80 %, the alkali loading of the concrete is calculated as follows:

$$KGA = 350(0.80/100) = 2.8\ kg/m^3$$
$$[LBA = 590\ (0.80/100) = 4.7\ lb/yd^3]$$

In a concrete containing 355 kg/m^3 [600 lb/yd^3] of Type IT(P30)(L10) ternary blended cement, with an equivalent alkali content of the portland cement and limestone fraction of 0.80 %, the alkali loading of the concrete is calculated as follows:

$$KGA = 355(70/100)(0.80/100) = 2.0\ kg/m^3$$
$$[LBA = 600\ (70/100)(0.80/100) = 3.4\ lb/yd^3]$$

The alkali content of the portland cement and limestone fraction of a Type IL or Type IT blended cement as illustrated in the example calculations above can typically be obtained on request from the manufacturer, even when this information is not reported on a mill test report. It can also be determined independently for a Type IL portland-limestone cement through testing a sample obtained by the user according to Test Methods C114.

3.2.3 *cement, n*—portland cement, portland-limestone cement, or the portland cement and limestone portion of a blended cement.

3.2.3.1 *Discussion*—This definition does not include slag cement because alkalies present in slag cement are not included in alkali loading calculations as shown in 3.2.2.1.

3.2.4 *deleteriously reactive, adj*—used to describe aggregates that undergo chemical reactions that subsequently result in premature deterioration of concrete.

3.2.4.1 *Discussion*—The term used in this standard guide describes aggregates that undergo chemical reactions with hydroxide (OH^-) in the pore solution.

3.2.5 *non-reactive, adj*—used to describe materials that do not undergo chemical reactions that subsequently result in premature deterioration of concrete.

3.2.5.1 *Discussion*—Some aggregates with minor amounts of reactive constituents may exhibit the symptoms of alkali-aggregate reaction (AAR) without producing any damage to the concrete; these are termed as non-reactive aggregates.

4. Summary of Guide

4.1 Alkali-aggregate reactions (AAR) occur between the alkali hydroxides in the pore solution of concrete and certain

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.
[4] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.
[5] Available from Canadian Standards Association (CSA), 5060 Spectrum Way, Suite 100, Mississauga, ON, L4W 5N4, Canada, http://www.csa.ca.