



REMOVAL OF OPTIONAL ALKALI LIMIT IN STANDARD SPECIFICATIONS FOR PORTLAND CEMENT

Introduction

Alkali-silica reactivity (ASR) is a potentially deleterious expansive reaction between alkalis in the pore solution of concrete and certain reactive aggregates. When ASR was first identified as a distress mechanism in the 1940s, cements with equivalent alkali contents below 0.60 percent by mass were shown to reduce the risk of this reaction. Subsequent research has shown that limiting the cement alkali content to 0.60 percent is not always sufficient to control deleterious ASR with every aggregate nor in all concrete mixtures. It is now well accepted that the reactivity of the aggregate and the amount of alkalis available in the concrete are more important in predicting deleterious ASR than cement alkali content alone.

Question

Why was the optional alkali limit removed from U.S. portland cement standards **ASTM C150/C150M** and **AASHTO M 85**?

Answer

Specifying a low-alkali portland cement by itself is not a recommended approach for mitigating ASR, and relying solely on the historic optional limit led to questionable results in the field. To make portland cement specifications ASTM C150/C150M and AASHTO M 85 consistent with current guidance on ASR, the optional alkali limit was removed from the specifications; however, reporting of the alkali content of the cement is now mandatory.

Background

ASTM C150 and AASHTO M 85 are common specifications for portland cement. Around 1961, an optional maximum limit of 0.60 percent equivalent alkali content by mass was inserted in these standards to represent a low-alkali cement. Specifications for concrete could invoke this limit for portland cement to be used with aggregates potentially susceptible to ASR.

The equivalent alkali content ($\% \text{Na}_2\text{O}_{\text{eq}}$) is a chemical characteristic of cement defined as shown in the following equation

$$\% \text{Na}_2\text{O}_{\text{eq}} = \% \text{Na}_2\text{O} + 0.658 \times \% \text{K}_2\text{O}$$

Specification changes

In 2018, ASTM and AASHTO committees independently reviewed and approved proposals to replace the optional maximum limit of 0.60 percent equivalent alkalis for low-alkali portland cement with a requirement to report the equivalent alkali content on mill test reports. The revised portland cement specifications, ASTM C150 and AASHTO M 85, were published in April 2019. Included with those changes was a note referencing **ASTM C1778**, "Standard Guide for Reducing the Risk of Deleterious Alkali-Aggregate Reaction in Concrete," or **AASHTO R 80**, "Standard Practice for Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction," to provide the most current guidance on establishing concrete mixture proportions to minimize ASR. Options for mitigation include both performance and prescriptive approaches.

Role of alkalis in cement and concrete

When portland cement is mixed with water, most alkalis in cement tend to be rapidly soluble and raise the pH of the pore solution of concrete to values higher than 13. The associated increase in pore-solution pH can provide additional impacts on concrete mixtures, such as:

- a) Enhancing the early hydration of portland cement
- b) Enhancing the rate of reactions of pozzolans such as fly ash, silica fume, and natural pozzolans
- c) Enhancing reactions of hydraulic materials such as slag cement
- d) Providing a passivation layer to protect reinforcing steel from corrosion
- e) Changing the performance of some air-entraining and chemical admixtures
- f) Increasing the risk of ASR, reactive aggregates in a high-alkaline environment, and in the presence of moisture, can form alkali-silica gel, which can then expand, exerting tensile stresses that could lead to concrete cracking (refer to [ACI 201.2R](#))

Controlling ASR

Alkali loading of a concrete mixture is a more important factor impacting deleterious ASR than the alkali content of the portland cement used. Alkali loading is the total amount of alkali in lb/yd³ (kg/m³) in the concrete and is calculated by multiplying the portland cement equivalent alkali content by the portland cement content in lb/yd³ (kg/m³) of the concrete

$$\text{alkali loading of concrete} = \frac{\% \text{Na}_2\text{O}_{\text{eq}} \times \text{portland cement content}}{100}$$

For example, using a portland cement with a 0.70 percent equivalent alkali content in a concrete mixture with 450 lb/yd³ (267 kg/m³) of portland cement has an alkali loading of 3.2 lb/yd³ (1.9 kg/m³), while using that same portland cement in a concrete mixture with 650 lb/yd³ (386 kg/m³) of portland cement has an alkali loading of 4.6 lb/yd³ (2.7 kg/m³). The use of slag cement, fly ash, or other supplementary cementitious materials (SCMs) can reduce the alkali loading in concrete. By comparison, a concrete mixture containing 650 lb/yd³ (386 kg/m³) of total cementitious materials with 40 percent being slag cement and a portland cement equivalent alkali content of 0.70 percent results in an alkali loading of 2.7 lb/yd³ (1.6 kg/m³).

Reactive aggregates can vary in degree of reactivity. The concrete alkali loading at which the risk of distress from ASR is minimized depends on several factors, including: characteristics of other materials (SCMs, for example) in the concrete, exposure conditions, and the level of risk resulting from ASR-related damage (for example, sidewalk versus nuclear containment structure). [ASTM C1778](#) and [AASHTO R 80](#) are current industry standards that provide guidance on testing aggregates and establishing mitigation procedures either using prescriptive or performance options. The option on alkalis establishes limits on concrete alkali loading, at 3.0 to 5.0 lb/yd³ (1.8 to 3.0 kg/m³) but does not set limits on alkali content of portland cement.

Summary

Relying solely on limiting the cement alkali content for controlling ASR expansion is outdated and potentially misleading. ASR is a potentially deleterious concrete durability issue and best-practice solutions are based on evaluating concrete aggregates, performing testing to demonstrate mitigation, or controlling concrete mixture proportions by calculating concrete alkali loading and using appropriate amounts of SCMs. Specifiers should review their specifications for concrete construction and revise them to remove any reference to low-alkali cement—because these are not currently defined in cement standards—and specify alternatives that are consistent with the guidance in [ASTM C1778](#) and [AASHTO R 80](#).