Federal Aviation Administration

Memorandum

Date: February 7, 2023

To: All Airports Regional Division Managers

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Subject: Engineering Brief No. 106, *Guidance for the Implementation of Changes in Industry Cement Standard Specifications*

This Engineering Brief (EB) provides interim guidance on the specification of cements to be used with construction of airfield pavements (cement treated subgrade, stabilized subbase, stabilized base, rigid pavement, and concrete for miscellaneous structures).

Attachment

FAA
Airports

ENGINEERING BRIEF #106

Guidance for the Implementation of Changes in Industry Cement Standard Specifications

I Purpose.

This Engineering Brief (EB) specifies design guidance for the selection of cement in pavement specifications in Advisory Circular (AC) 150/5370-10H, *Standard Specifications for Construction of Airports*.

II Background.

The Federal Aviation Administration (FAA) has identified a need for guidance for specifying which cement to use with pavement specifications. The use of blended cements as specified in ASTM International (ASTM) C595 / American Association of State Highway and Transportation Officials (AASHTO) M240 is becoming more common due to the reduced carbon footprint of blended cements as compared to traditional portland cements. ASTM C150 / AASHTO M80 no longer includes the option for low-alkali cement. This EB addresses the cements appropriate for use on airport pavement construction and how and when it is necessary to report the alkali content of cement.

III Application.

This EB is intended as interim guidance for the specification of cement for use in subgrade, subbase, base, and pavements.

IV Questions.

Contact the FAA's Harold Honey at harold.honey@faa.gov, Jeff Crislip at jeffrey.d.crislip@faa.gov, Harold Muniz at harold.muniz-ruiz@faa.gov, or the current designated pavement engineers for any questions about this EB.

V Effective Date.

This EB is effective after signature by the Manager of the FAA Airports Engineering Division, AAS-100.

VI Applicable Documents.

AC 150/5370-10, *Standard Specifications for Construction of Airports.*

Table of Contents

1.0 Introduction.

1.1. EB Guideline Justification.

Many cement producers have transitioned from the production of *Types I and II* plain cements, as specified in ASTM C150, to producing blended hydraulic cements such as portland-limestone cement (IL) and other blended cements, as specified in ASTM C595. In addition, ASTM C150 eliminated the optional requirement of "low alkali" cements, and ASTM C595 has added a special property designation, HE, for high-early strength. This EB addresses what cements are appropriate for use on airport pavement construction and how and when it is necessary to report the alkali content of cement. **Note:** This EB does not change the need to perform aggregate reactivity testing following ASTM C1260 and aggregate mitigation testing following ASTM C1567 as specified in AC 150/5370-10.

1.2. Explanation of Terms.

Terms used in this EB:

1. *Alkali Content, Na_2Oeq*: Value in percent, determined by reporting the sodium and potassium oxides determined using the procedure in ASTM C114 for determination of sodium and potassium oxides in hydraulic cements. Report the equivalent alkali content using the following formula: $Na_2Oeq = \%\ Na_2O + 0.658 \times \%\ K_2O$.
2. *Alkali Loading*: Amount of alkalies contributed by the cement in a concrete mixture, expressed in lb/yd^3 or kg/m^3, calculated by multiplying the portland cement fraction of the concrete in lb/yd^3 or kg/m^3, by the alkali content of the portland cement or the portland cement portion of a blended cement divided by 100.

1.3. State/Local Role.

State regulators, Departments of Transportation (DoTs), and local communities can use the guidance and best practices outlined in this EB.

2.0 Sustainable Cements.

2.1. CO_2 Emissions.

The use of blended cements has environmental and performance-related benefits. Blended cements, as specified in ASTM C595, contribute to sustainable construction by conserving natural resources and lowering energy consumption during manufacturing resulting in reduced CO_2 emissions. Generally, blended cements are acceptable to use in place of plain cements, as specified in ASTM C150, on a 1:1 replacement. Blended cements are often more economical, increase strength and durability, and influence other properties such as water demand or reactivity of aggregates.

2.2. When to Specify Blended Cements.

It is acceptable to use blended cements with P-153, P-207, P-220, P-307, P-501, or P-610. The FAA encourages project engineers to specify all appropriate cements available in the project area. The engineer should verify the availability of cements in the project area; not all cements are available in all regions.

2.3. When to Specify Standard Portland Cements.

If blended cements are not available in the area, specify ASTM C150 *Type I, II, or V* cements.

3.0 Alkalies in Cement.

3.1. What are Alkalies in Cement?

Alkalies in cement and concrete refer to the amount of alkali metal elements (lithium, sodium, potassium, rubidium, cesium, francium) present in the cement or concrete in readily soluble compounds. Sodium (Na) and potassium (K) ions supply most of the alkali in concrete. Alkalies are inherently present in some of the raw materials used to produce cement. Alkalies cannot be eliminated from cement and the content can only be controlled to a limited degree in the manufacturing process; there is not currently a way to predetermine a target or desired alkali content. The alkali content of cement is relatively consistent for individual plants.

3.2. Why the Concern with the Alkali Content of Cement?

The alkalies, or the hydroxides thereof, contribute greatly to the pH or alkalinity of the cement paste. The higher the content of alkalies, the higher the pH of the pore water within the cement paste. Certain aggregate types have amorphous (glassy) and/or poorly crystalized forms of silica. In highly alkaline environments, these forms of silica can become unstable and susceptible to reacting with the alkalies present in the pore water resulting in what is known as alkali-silica reaction (ASR). This reaction forms alkali-silica gel which can swell causing deleterious expansion within the aggregate particle, the cement paste, or both. This expansion can lead to cracking and subsequent degradation of the concrete.

3.3. Alkali Content.

For many years, based upon early research, the belief was that if the alkali content of the cement was below a certain level, that deleterious ASR reactions could be minimized. This was the basis for the adoption of the maximum alkali limit of “low alkali” cement as $Na_2Oeq < 0.6\%$.

However, a limit on the percent of equivalent alkalies in the cement alone did not address the total alkali loading of the concrete. The alkali loading of the concrete takes into consideration the cement content of the concrete and the alkali content of the cement. ASTM C150 no longer includes an option for low-alkali cement, but rather requires the cement manufacturer to report the equivalent alkali content of the cement on the mill test report. ASTM C595 also requires reporting of the equivalent alkali content of the portland cement component at the request of the purchaser.

3.4. Equivalent Alkali “Na_2Oeq”.

Sodium and potassium are the predominant alkalies present in cement. However, since sodium and potassium have different molecular weights, adjustments are required so that the reported weights are based upon an equal footing rather than just providing the sum of sodium and potassium. This result is known as the “equivalent alkali” content and often referred to as Na_2Oeq. Na_2Oeq is the sum of: $Na_2O + 0.658\ K_2O$. (**Note**: The 0.658 factor is the ratio of the molecular weights of sodium and potassium.) On a mill test, the "alkalies" are reported as "Na_2Oeq", or "equivalent alkali", or "total alkali", as tested in accordance with ASTM C114.

3.5. When to Limit Alkali Loading of Concrete Mixture

When either the fine or coarse aggregate to be used in P-501, *Cement Concrete Pavement*, or P-610, *Concrete for Miscellaneous Structures*, is potentially reactive, as determined by the ASTM C1260 test and as outlined in paragraphs 4.5 and 4.6, limit the alkali loading of the concrete mixture to be less than or equal to 3.0 lb/yd^3 (1.8 kg/m^3).

3.6. How to Calculate Alkali Loading of Concrete Mixture.

The alkali loading of concrete (lb/yd^3) = portland cement fraction content (lb/yd^3) × equivalent alkalies % Na_2Oeq × 1/100. **Note:** In concrete that includes supplementary cementitious materials, only the alkali content of the portland cement fraction of the cementitious materials is included in the calculations of alkali loading.

For example, consider a concrete mix containing 575 lbs/yd^3 of ASTM C595 *Type IL* (15) cement which is 85% portland cement, 15% limestone. If the equivalent alkali content of the portland cement component is 0.63% Na_2Oeq, the alkali loading of concrete would be:
575 lbs/yd^3 × 85/100 × 0.63/100 = 3.1 lbs/yd^3. (**Note:** In this case the mix designer must reduce the cement content or use a different cement to get the alkali loading below 3.0 lb/cy.)

For another example, consider a concrete mix containing 600 lbs/yd^3 of ASTM C595 Type IP (20) cement which is 80% portland cement, 20% pozzolan. If the equivalent alkali content of the portland cement component is 0.59% Na_2Oeq, the alkali loading of concrete would be:
600 lbs/yd^3 × 80/100 × 0.59/100 = 2.8 lbs/yd^3.

4.0 Modifications to AC 150/5370-10H.

This section provides modifications to AC 150/5370-10H for specifying cements to be used for subgrade, subbase, base, cement pavement, and miscellaneous concrete. Using the modifications included in this EB does not require submitting a formal request for a modification of standards (MOS). Replace the appropriate paragraph in AC 150/5370-10H with paragraphs 4.1 through 4.6.

4.1. P-153 Controlled Low-Strength Material (CLSM).

153-2.1a. Cement. Cement: ASTM C150, *Types I*, *II*, or *V*; ASTM C595, *Types IS*, *IP*, *IL*, or *IT*.

4.2. P-207 In-place, Full-Depth Reclamation (FDR) Recycled Asphalt Aggregate Base Course.

207-2.2b. Chemical Stabilization. Cement: ASTM C150, *Types I*, *II*, or *V*; ASTM C595, *Types IS*, *IP*, *IL*, or *IT*.

4.3. P-220 Cement Treated Soil Base Course.

220-2.1 Cement. Cement: ASTM C150, *Types I*, *II*, or *V*; ASTM C595, *Types IS*, *IP*, *IL*, or *IT*.

4.4. P-307 Cement Treated Permeable Base Course (CTPB).
307-2.3. Cement. Cement: ASTM C150, *Types I*, *II*, or *V*; ASTM C595, *Types IS*, *IP*, *IL*, or *IT*.

4.5. P-501 Cement Concrete Pavement.
501-2.1 a. (1) Test coarse aggregate and fine aggregate separately, in accordance with ASTM C1260; however, extend the length of the test to 28 days (30 days from casting). Complete the tests within six months of the date of the concrete submittal. If expansion of either the coarse or fine aggregate exceeds 0.10% at 28 days, limit the alkali loading of the concrete to be less than or equal to 3.0 lb per cubic yard (1.8 kg per cubic meter), calculated in accordance with EB 106.

Note: Remaining parts of 501-2.1a remain as in AC 150/5370-10H.

501-2.2 Cement. Cement: [ASTM C150, *Types I*, *II*, or *V*; ASTM C595, *Types IS*, *IP*, *IL*, or *IT;* ASTM C1157 *Types GU, HS, MS, MH, or LH*]

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The engineer should retain all cements appropriate for use on the project.
Note: ASTM C1157 cements are typically only used for repair projects.
Other cements may be specified with the concurrence of the FAA.

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501-3.4 Concrete Mix Submittal. Add the following information to the Concrete Mix submittal requirements list:

- Alkali loading contributed by the cement per cubic yard, calculated in accordance with EB 106.

4.6. P-610 Concrete for Miscellaneous Structures.

Add the following to the end of the first paragraph in 610-2.1a:

610-2.1a If expansion of either the coarse or fine aggregate exceeds 0.08% at 14 days, limit the alkali of the concrete to be less than or equal to 3.0 lb per cubic yard (1.8 kg per cubic meter), calculated in accordance with EB 106.

610-2.4. Cement. Cement: [ASTM C150, *Types I*, *II*, or *V*; ASTM C595, *Types IS*, *IP*, *IL*, or *IT;* ASTM C1157 *Types GU, HS, MS, MH, or LH.*]

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The engineer should retain all cements appropriate for use on the project.
Note ASTM C1157 cements are typically only used for repair projects. Other cements may be specified with the concurrence of the FAA.

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Acronym List

AASHTO	American Association of State Highway and Transportation Officials
AC	Advisory Circular
ASR	Alkali-Silica Reaction
ASTM	ASTM International
CLSM	Controlled Low-Strength Material
CO_2	Carbon dioxide
CTPB	Cement Treated Permeable Base Course
DoT	Departments of Transportation
EB	Engineering Brief
FAA	Federal Aviation Administration
FDR	Full-Depth Reclamation
GU	General Use
HE	High-early
HS	High Sulfate Resistance
IL	Portland-limestone cement
IP	Portland-pozzolan cement
IS	Portland blast-furnace slag cement
IT	Ternary blended cement
K	Potassium
LH	Low Heat of Hydration
MH	Moderate Heat of Hydration
MOS	Modification of Standards
MS	Moderate Sulfate Resistance
Na	Sodium