Specification in Practice

What, why & how?

SIP 4 – Restrictions on Type and Characteristics of Fly Ash

by the NRMCA Research Engineering and Standards Committee

WHAT restrictions to fly ash are seen in specifications?

Typical restrictions to fly ash seen in specifications for concrete include:

- Class C fly ash is not permitted
- The calcium oxide (CaO) content of fly ash shall not exceed XX%
- The Loss on Ignition (LOI) of fly ash shall not exceed X.X% (more restrictive than ASTM C618)
- Fly ash fineness—The percent retained on the 45 µm (No. 325) sieve shall not exceed XX% (more restrictive than ASTM C618)
- The [available] alkali content of fly ash shall not exceed X.X%

In an NRMCA review of more than 100 specifications for private work, these types of restrictions were noted in 25% of the specifications, 80% of which did not allow the use of Class C fly ash or had restrictions on the CaO content of the fly ash.

DO industry standards have restrictions on fly ash?

ACI 318-14 permits the use of fly ash that complies with ASTM C618. It imposes no additional restrictions on the characteristics of fly ash.

ASTM C618 classifies fly ash as Class F or Class C based on composition and has the following requirements:

Requirement	Class F	Class C
(SiO_2 + Al_2O_3 + Fe_2O_3), min %	70.0	50.0
Loss on Ignition (LOI), max %	6.0*	6.0
Fineness, retained on 45 µm (No. 325) sieve, max %	34	34

*ASTM C618 permits up to 12% LOI with documented service records or laboratory evaluation.

Additionally, there are limits on sulfur trioxide (SO_3), moisture content, soundness, strength activity index, water requirement, and uniformity requirements for material from a single source. Optional requirements, when specifically requested, are also covered in the specification. There are no limits on alkali content of fly ash, but the supplier may report this, expressed as equivalent sodium oxide (Na_2O).

WHAT is the basis for these restrictions?

In general, Class F fly ashes are more effective in mitigating deleterious expansion due to alkali-silica reaction (ASR) and improving the sulfate resistance of concrete. Fly ashes with higher CaO content are less effective when these durability conditions exist (Thomas 2007). A limit on available alkalis was removed from ASTM C618 in the 1990s based on work that indicated that the available alkalis in fly ash were not a good indicator when considering the use of fly ash in concrete containing potentially reactive aggregate (Smith 1987). However, specifying Class F fly ash does not ensure that the concrete will be resistant to ASR and sulfate attack. A methodical approach to addressing ASR is covered in ASTM C1778. Sulfate resistance of concrete is addressed in ACI 318-14 and the effect of fly ash in improving sulfate resistance is covered in the optional requirements of ASTM C618.

LOI is a measure of the amount of unburnt carbon in fly ash. Certain forms of unburnt carbon absorb air-entraining admixtures and affect the air content of air-entrained concrete. Research has indicated that at the same LOI, fly ash from different sources can exhibit varying impacts on air entrainment (Hill and Folliard 2006). It was also observed that fly ashes with lower LOI were more sensitive to air entrainment. Possible reasons for the varying impacts are total carbon surface area, available surface area, and surface reactivity of the carbon (ACI 232.2R-03). Imposing a lower LOI limit on fly ash does not ensure better control of the air content in air-entrained concrete. The concrete producer is responsible for achieving the specified air content in concrete.

Specifying more restrictive fineness requirements on fly ash could be an attempt to ensure that a more reactive material is used. Research on this aspect indicates that when fineness of fly ash from the same source varied substantially (between 15% and 30%) over a period of time, there was no significant difference in strength of mortar cubes (Obla 2014). Besides fineness, fly ash reactivity is impacted by factors such as chemical and physical composition, morphology, and the portland cement with which it is used (ACI 232.2R-03). The concrete producer is responsible for supplying concrete mixtures that meet the specified strength requirements.

WHAT problems do these restrictions cause?

- Fly ash may need to be obtained from distant sources and the concrete producer will need to gain experience on optimized use;
- Locally available materials that have history of acceptable mixture performance and service record

are restricted from use; and

- There is a false sense of security that imposing restrictions ensures achievement of the intended performance.

Additional guidance and rationale for eliminating prescriptive requirements in specifications are provided elsewhere (NRMCA 2012; NRMCA 2015).

WHAT is the alternative to this specification requirement?

- As an alternative to prohibiting Class C fly ash or imposing a limit on the CaO content of fly ash, consider performance-based tests:
  - ◊ For ASR, ASTM C1778 provides a reasonable and rather detailed approach; ASTM C1567 expansion test results equal to or less than 0.1% at 14 days when the fly ash is used with the producer's aggregates and cementitious materials;
  - ◊ For sulfate resistance, consider the performance requirements of ACI 318-14 or the optional requirements of ASTM C618 that evaluate the ability of fly ash to improve sulfate resistance of concrete based on ASTM C1012/C1012M testing;
- Do not include more restrictive requirements on LOI or fineness than those in ASTM C618. The market will determine the acceptability of fly ash. The fly ash supplier and concrete producer are responsible for monitoring the quality and uniformity of fly ash to ensure that the specified air content and strength are achieved (Obla 2014).

WHAT is the benefit of the alternative requirements?

Alternative performance requirements ensure that concrete attains improved durability such as resistance to ASR and sulfate attack. Limiting the use to only Class F fly ash does not ensure improved concrete durability.

Mitigation of ASR has been attained by increasing the percentage of Class C fly ash, or by using Class C fly ash with other supplementary cementitious materials (SCMs) and lithium based admixtures (Shehata and Thomas 2000). Sulfate resistance has been attained with ternary blends of Class C fly ash and silica fume (Shashiprakash and Thomas 2001). The alternative performance requirements can make it feasible to use locally available Class C fly ash sources that results in cost-effective concrete mixtures, and supports sustainability initiatives.

Eliminating restrictive limits on the LOI and fineness of fly ash will permit the use of fly ash sources available in some markets that might otherwise be restricted. These restrictions do not ensure concrete performance.

References

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4. ASTM C1012/C1012M, "Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution."
5. ASTM C1567, "Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)."
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