



LIMITS ON THE PROPORTIONS OF FLY ASH IN CONCRETE

Introduction

This TechNote discusses the implications of limits on the proportions of fly ash in project specifications. This TechNote addresses only fly ash that meets current, applicable specifications such as [ASTM C618](#). Prescriptive specifications for concrete construction projects often include a clause that limits the proportion of supplementary cementitious materials (SCMs) ([Obla and Lobo 2015](#)). For example, the clause incorporated in Section 033000 pertaining to cast-in-place concrete from the [MasterSpec \(2014\)](#) states:

Cementitious Materials: [Limit percentage, by mass, of cementitious materials other than portland cement in concrete as follows:]

1. Fly Ash: 25 percent.
2. Combined Fly Ash and Pozzolan: 25 percent.
3. Slag Cement: 50 percent.
4. Silica Fume: 10 percent.

MasterSpec (2014) notes inform the designer that this clause is used for concrete exposed to freezing-and-thawing cycles and the application of deicing salts. This advice, however, seems to be ignored by specification writers. In an NRMCA review of more than 100 specifications ([Obla and Lobo 2015](#)) for projects funded by private agencies, these limits were noted in 85 percent of the specifications, without consideration of the anticipated exposure condition for concrete members. Some specifications specifically prohibited the use of SCMs.

Question

Should limits on the proportion of fly ash meeting ASTM C618 in concrete be specified?

Answer

Limits on the percentage of fly ash that meet ASTM C618 are generally unnecessary if relevant fresh and hardened concrete performance requirements are specified. An exception is the case where the concrete will be exposed to deicer chemicals in a freezing-and-thawing environment when building code limits apply.

Industry standards—Provided as one example, Table 1 replicates Table 26.4.2.2(b) in [ACI 318-14](#), which establishes limits on the proportion of SCMs for concrete members in Exposure Class F3, defined as “concrete exposed to freezing-and-thawing cycles with frequent exposure to water and exposure to deicing chemicals.” Additionally, ACI 318 requires air entrainment, a maximum water-cementitious materials ratio (w/cm) of 0.40, and a minimum specified strength of 5000 psi (35 MPa) for structural concrete. Plain concrete requires air entrainment, but the limits on w/cm and specified strength are 0.45 and 4500 psi (31 MPa), respectively.

Table 1—Limits on cementitious materials for concrete assigned to Exposure Class F3 (Table 26.4.2.2(b) in ACI 318-14)

Cementitious materials	Maximum percent of total cementitious materials by mass, %
Fly ash or other pozzolans conforming to ASTM C618	25
Slag cement conforming to ASTM C989/C898M	50
Silica fume conforming to ASTM C1240	10
Total of fly ash or other pozzolans and silica fume	35
Total of fly ash or other pozzolans, slag cement, and silica fume	50

The basis—ASTM C672/C672M has been shown to be an unduly harsh procedure and may overstate the scaling potential of mixtures containing fly ash (Thomas 1997). A more realistic test has shown that concrete with up to 35 percent fly ash, the highest level evaluated in that study, has shown satisfactory performance in scaling resistance (Bouzoubaa et al. 2008). A significant factor in concrete surface defects, such as scaling, is related to improper concrete finishing and curing (NRMCA 1998). Hand-finished concrete flatwork, such as sidewalks and driveways, are most susceptible to scaling (Thomas 2007). It has been suggested by ACI 201.2R that the Table 1 limits for SCMs be made applicable only for hand-finished surfaces and not formed and machine-finished surfaces. Whereas much of the earlier discussion pertains to the physical failure mechanism of deicer salt scaling, deicers such as calcium chloride can react with calcium hydroxide present in hardened concrete and form calcium oxychloride, an expansive product that can cause disruption (Sutter et al. 2008). Pozzolans such as fly ash can consume the calcium hydroxide and thereby reduce the formation of calcium oxy-chloride (Sutter et al. 2008; Suraneni et al. 2016). The use of fly ash generally increases the setting time and decreases the early-age strength of concrete. This may be acceptable in warm weather but can be a concern for construction in cooler weather. Restricting the proportion of fly ash can be an implicit attempt to attain shorter setting times and increased early-age strengths. A research study (Malhotra and Ramezani pour 1994) using 11 Class F fly ash sources illustrated that setting time and early-age strength of 20 percent fly ash mixtures can vary widely, being similar to or considerably delayed in comparison to control concrete mixtures without fly ash. Concrete temperature also impacts the setting time and strength development of concrete. Restricting the proportion of fly ash does not assure control of setting time and early-age strength. Concrete producers can proportion mixtures to achieve required setting times and early-age strengths by using fly ash quantities in excess of those in Table 1, and through the use of chemical admixtures and other parameters (Jeknavorian 2014; Obla et al. 2003). Concrete mixtures with up to 85 percent SCMs, by mass of cementitious materials, have been used in structural members to achieve the performance requirements mandatory on some projects (American Concrete Institute 2009; Kite 2005).

The problem—By limiting the proportion of fly ash:

- There is no assurance that mixtures will have the desired setting times and early-age strengths.
- Workability/pumpability and water demand can be adversely impacted.
- Resistance to later-age durability problems, such as alkali silica reaction (ASR) or sulfate attack, cannot be attained in some cases (Thomas 2007).
- Temperature control in mass concrete members, including maximum temperature and rate of temperature rise, can be difficult to achieve when fly ash quantities are limited (Langley et al. 1992).
- Reduced permeability of concrete can be difficult to achieve and this could impact durability, specifically by reducing the time to onset of corrosion of reinforcing steel (Thomas 2004). Later-age development of strength and other mechanical properties of concrete can be curtailed.

The alternatives

- Delete limits on quantities of fly ash in concrete mixtures, except those limits for concrete used in members that would be assigned to Exposure Class F3, as defined previously.
- Include performance-based requirements such as strength and durability when required for the project.