

Specification in Practice

What, why & how?



SIP 1 – Limits on Quantity of Supplementary Cementitious Materials

by the NRMCA Research Engineering and Standards Committee

WHAT is the typical specification requirement?

The typical clause incorporated in specifications from the AIA MasterSpec (2014) is:

Cementitious Materials: [Limit percentage, by weight, 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...

The 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. However, this advice seems to be ignored by specification writers. In an NRMCA review of more than 100 specifications for private work, these limits were noted in 85% of the specifications, without consideration of the anticipated exposure condition for concrete members. Some specifications specifically prohibit the use of supplementary cementitious materials (SCMs).

Do industry standards require limits on SCM quantities?

Table 1 replicates Table 26.4.2.2(b) in ACI 318-14, which establishes limits on the quantity 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”. The concern is that surface scaling will reduce cover and result in reinforcement corrosion. Additionally, ACI 318-14 requires air entrainment, a maximum water-cementitious materials ratio (w/cm) of

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	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

0.40, and a minimum specified strength of 5000 psi (35 MPa) and for structural concrete. The limits on w/cm and specified strength are 0.45 and 4500 psi (31 MPa), respectively, for plain concrete.

ACI 301-10 includes the above limits and additionally limits fly ash in concrete for floors to 15 minimum and 25% maximum by weight of cementitious materials unless otherwise specified.

The committee is not aware of other industry standards that place limits on the quantity of SCMs in concrete mixtures.

WHAT is the basis for this specification requirement?

Research conducted by Malhotra and Mehta (2012) has indicated that concrete mixtures containing higher quantities of SCMs than those shown in Table 1 have not performed well in tests conducted in accordance with ASTM C672/C672M. However, it is generally understood that the ASTM C672/C672M test is unduly harsh for mixtures containing fly ash and slag cement (Thomas 1997) and results from a more realistic test could allow the use of greater amounts of SCMs (Bouzoubaa et al. 2008). A significant factor in concrete surface defects such as scaling is related to improper concrete finishing and curing (CIP 2). Scaling is observed for higher slump concrete finished by manual methods and is rarely seen in machine finished concrete, as in slipform construction (Thomas 2007).

The use of SCMs generally increases the setting time and decreases the early age strength of concrete. This is beneficial in warm weather but can be a concern for construction in cooler weather. Restricting the quantity of SCMs can be an implicit attempt to attain shorter setting times and increased early age strengths. A research study using 11 fly ash sources illustrated that setting time and early-age strength of 20% fly ash mixtures can vary widely – they can be similar to or considerably delayed when compared to control mixtures without fly ash (Malhotra and Ramezani-pour 1994). Concrete temperature also has an effect on these properties of concrete. So, restricting the SCMs quantity does not assure control of setting time and early-age strength.

How can these limits be restrictive?

- Workability/pumpability can be adversely impacted;
- With some materials, and under some conditions, the quantity of SCMs allowed can be inadequate to prevent later-age durability problems, such as alkali silica reaction (ASR) or sulfate attack;
- Temperature control in mass concrete members can be difficult to achieve;
- 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; and
- Later-age development of strength and other mechanical properties of concrete can be curtailed.

WHAT is the alternative to this specification requirement?

- Delete limits on quantities of SCMs in concrete mixtures, except those limits for concrete used in members that would be assigned to Exposure Class F3 as defined above;
- Include performance-based requirements, such as early age strength, when required for the project; and
- Allow construction-related requirements for time of setting, finishability, and formwork removal to be set through separate contracts, purchase orders, and at pre-construction meetings between producers and contractors.

How can these alternative requirements benefit the project?

It is well researched and established that concrete with SCMs has enhanced workability as well as improved mechanical and durability properties (ACI 232.1R-12, 232.2R-03, 232.3R-14, 233R-03, 234R-06, CIP 30). Some of these beneficial properties may not be achieved with mixtures containing only portland cement or if there are restrictions on the quantity of SCMs, specifically:

- Improved resistance to ASR and sulfate attack;
- Enhanced durability of concrete related to chloride-induced corrosion;
- Continued improvement in later-age properties that can increase the service life of structures; and
- Achievement of more sustainable construction.

Concrete producers can optimize concrete mixtures to achieve required setting times, early age strengths, or concrete temperature requirements for mass concrete by using SCM quantities in excess of those in Table 1, through the use of chemical admixtures, and other parameters (Jeknavorian 2014; Obla et al. 2003). These requirements need to be clearly stated. Placing restrictions on quantities of SCMs may not allow mixtures to achieve the desired performance. In contrast to this, concrete mixtures with up to 85% SCMs by weight of cementitious materials have been used in structural members to achieve the performance requirements mandatory on some projects (Concrete International 2009; Kite 2005).

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2015



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