

Specification in Practice

What, why & how?



SIP 3 – Minimum Cementitious Materials Content

by the NRMCA Research Engineering and Standards Committee

WHAT is the typical specification requirement?

The typical clause in specifications for concrete states:

Concrete for XXX members shall comply with the following:

Minimum cement content xxx lb/yd³

Note: The limit on minimum cement content is sometimes stated as minimum content of cementitious materials.

In an NRMCA review of more than 100 specifications for private work, these limits were noted in 46% of the specifications. Specifications that stated these limits for interior slabs-on-ground were not counted.

Do industry standards include a minimum cement content?

There is no requirement for minimum cement or cementitious materials content in ACI 318-14.

ACI 301-10 has minimum cementitious materials content requirements only for interior floor slabs (see Table 1). These limits are considerably lower than that seen in some specifications. The intent is to ensure adequate paste to facilitate finishability. A test slab placement is permitted as an alternative to the minimum cementitious content requirement.

Table 1: Minimum cementitious materials content requirements for floors (Table 4.2.2.1 in ACI 301-10)

Nominal maximum size of aggregate, in.	Minimum cementitious materials content, lb/yd ³
1-1/2	470
1	520
3/4	540
3/8	610

Note: When fly ash is used as a supplementary cementitious material, quantity shall not be less than 15% nor more than 25% by weight of total cementitious material, unless otherwise specified.

Note: 1 in. = 25 mm; 1 lb/yd³ = 0.6 kg/m³

WHAT is the basis for this specification requirement?

Historically, when concrete was proportioned with only portland cement, a minimum cement content was commonly specified to ensure that the strength and durability requirements were met. The perception still remains that some minimum cement content is required to ensure durability, even though there is now an adequate understanding that using supplementary cementitious materials (SCMs) is an essential method for improving most prop-

erties of concrete related to durability. Sometimes, the specified cement content is an implicit control on the quantity of SCMs.

Wasserman et al. (2009) identified three possible reasons for specifying a minimum cementitious content:

1. It provides assurance that a low water-cementitious materials ratio (w/cm) is attained, even if good control of the mixing water content is not exercised.
2. It ensures there is enough paste to fill the voids between the aggregates and provide adequate workability, and
3. It offers corrosion protection by chemically binding the chlorides and CO₂ that penetrate the concrete.

Wasserman et al. (2009) and Dhir et al. (2003) reported that at any given w/cm , increasing cement contents lead to similar compressive strengths and carbonation rates, but higher absorption and chloride penetration. A mixture with higher cement content had increased chloride thresholds to initiate corrosion but this benefit was offset by higher chloride penetration. Dhir et al. (2003) reported that for mixtures with similar w/cm values, increasing cement contents led to similar flexural strengths, moduli of elasticity, and levels of deicer salt scaling. However, increasing cement contents led to reduced sulfate resistance, increased chloride diffusion, greater air permeability, and higher length change due to shrinkage. These studies concluded that the minimum cementitious materials content should not be specified for concrete durability.

Obla (2012) and Yurdakul (2010) looked at a broader range of cementitious materials contents and found that increasing cement content at a given w/cm did not result in higher strength. With increasing cement contents, concrete resistance to chloride penetration was reduced and shrinkage increased. Mixtures with very low paste contents resulted in poor workability and reduced compressive strengths. It should be noted that ACI 211.1-91 mixture proportioning approaches typically yield adequate paste volume for workability.

HOW can these limits be restrictive?

The specified cement content:

- May be much higher than the amount needed to meet the performance requirements;
- Can impact the ability to place and finish the mixture in some applications;
- Can increase the paste volume in the mixture, increasing potential for cracking due to plastic or drying shrinkage and temperature effects;
- Can increase the alkali content in the mixture and

cause an alkali aggregate reaction problem;

- May result in a mixture that fails to achieve expected and unstated durability objectives;
- Is not supportive of sustainable construction; and
- Places competitive bids that support quality and performance at a disadvantage.

WHAT is the alternative to this specification requirement?

- Delete limits on content of cement or cementitious materials for concrete mixtures;
- Specify the performance requirements for the project (NRMCA 2012, NRMCA 2015) (there is no technical basis for specifying cement content if the performance requirements are defined);
- Invoke the durability requirements of ACI 318-14, by specifying w/cm and appropriate compressive strength, and other requirements when applicable (NRMCA 2012).
- Consider requiring a test floor slab placement or documentation of successful past field history as an alternative to specifying the cement content;
- Specify an appropriate compressive strength rather than a minimum cementitious materials content if a low w/cm is required, as compressive strength is a better indicator of w/cm ; and
- If the implicit purpose is to ensure improved quality, require and review the quality plan of the producer and contractor (NRMCA administers a quality certification program for concrete producers (NRMCA 2013)).

How can these alternative requirements benefit the project?

Specifying compressive strength that is consistent with the required w/cm for durability provides better assurance for durable concrete than specifying cement content. In contrast, specifying a minimum cementitious

materials content does not ensure a low w/cm or improved durability. In fact, such a specification benefits entities that have not made investments in quality and provides no incentive to optimize mixtures for performance.

Figure 1 illustrates a poor level of quality on a project. The specified strength was 4000 psi (28 MPa), with a minimum cementitious content of 650 lb/yd³ (390 kg/m³). The coefficient of variation of strength results was 18.3%, which is categorized as poor control, according to ACI 214R-11. There were no low strength test results and, as a result, there was no incentive to reduce variability. This does not benefit the owner.

A survey of the ready mixed concrete industry (Obla 2014) revealed that the average cementitious material content used in a cubic yard of concrete is about 100 lb/yd³ (59 kg/m³) more than that required to meet the strength requirement. This represents a waste of resources and is not supportive of sustainable construction. Mixtures with lower cementitious materials content can be proportioned and this can lead to improved workability and durability as well as reduced potential for cracking.

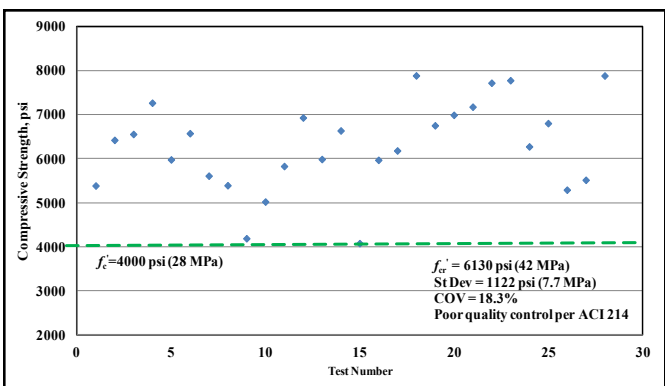


Figure 1: Variability of compressive strength test results from a project with a specified minimum cementitious materials content requirement

References

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