

Things to Consider When Specifying **WATER** to **CEMENTITIOUS** Material Ratios



**Concrete Information
for the Owner, Designer,
Contractor and Producer**

Limits on maximum water-cementitious material ratios (w/cm) are frequently noted in concrete construction specifications. Specifying the proper w/cm is good practice where there are exposure conditions that warrant it. However, problems often arise when w/cm ratios are specified where the exposure conditions do not warrant it, when they are specified globally for all concrete on a project, or when they are specified in contradiction to compressive strength. Those problems may include added costs, estimating errors and field errors.

ACI 211.1 (Table 1, right) provides the approximate relationship between compressive strength and w/cm.

Further, ACI 318-14 specifically states maximum w/cm in its durability provisions for concrete members. The design professional assigns the member to a durability exposure class based on the anticipated exposure of the member in service. ACI 318-14 requires maximum w/cm and minimum specified strength for these conditions as follows:

Table 1 - Relationship Between Water to Cementitious Material Ratio and Compressive Strength of Concrete

Compressive Strength At 28-days psi	Water-cementitious materials ratio by mass	
	Non-air entrained concrete	Air-entrained concrete
7000	0.33	-----
6000	0.41	0.32
5000	0.48	0.40
4000	0.57	0.48
3000	0.68	0.59
2000	0.82	0.74

Exposure Condition	Maximum w/cm, by weight normal weight concrete	Minimum f'_c , normal weight and lightweight concrete, psi
Condition protected from exposure to freezing and thawing, application of deicing chemicals, or aggressive substances	Select water-cementitious material ratio on basis of strength, workability, and finishing needs	Select strength based on structure requirements
Concrete intended to have low permeability when exposed to water	0.50	4000
Concrete exposed to freezing and thawing in a moist condition or deicing chemicals	0.45	4500
For corrosion protection of reinforcement in concrete exposed to chlorides from deicing chemicals, salt, salt water, brackish water, seawater, or spray from these sources	0.40	5000

Chapter 19 of ACI 318-14 provides additional w/cm requirements for other exposure conditions.

As we can see on the charts provided, a 3500 psi non air-entrained interior floor concrete should not have a maximum w/cm specified. A 4000 psi air-entrained exterior concrete should be not be specified with a .40 w/cm. That w/cm ratio will yield 5000 psi concrete; greater than what is required.

The primary intent of specifying w/cm limits is to reduce the penetration of water and dissolved chemicals into concrete. The w/cm should not be specified if the exposure condition does not warrant it. While w/cm is an important parameter for a concrete mixture, there is a perception that a low w/cm helps to ensure good concrete performance (low shrinkage and less cracking). That does not always correlate.

PACA ready mixed concrete company members take great care in developing concrete mixtures whose proportions will achieve the desired performance characteristics (compressive strength and resistance to damage from exposure conditions) noted in this document. Specifying w/cm requirements only when necessary for improved durability ensures that concrete mixtures can be optimized and developed for the performance required by the specific application. It is important that the w/cm ratio and strength requirements specified are consistent with the durability provisions of ACI 318-14, thus ensuring that the specification requirements can be enforced using the strength acceptance criteria.

References:

- ACI Committee 318, *Building Code Requirements for Structural Concrete*, American Concrete Institute, Farmington Hills, MI
- ACI Committee 211, *Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete*, American Concrete Institute Farmington Hills, MI
- "What, Why & How – Limits on Water-Cementitious Materials Ratio (w/cm), *Specification in Practice Note 2*, National Ready Mixed Concrete Association, 900 Spring Street, Silver Spring, Maryland
- *Design and Control of Concrete Mixtures*, 14th Edition, Portland Cement Association, 5420 Old Orchard Road, Skokie, IL

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