



# Texas Aggregates and Concrete Association

## Position Statement #7

### The Misconception of W/CMT Ratio Design

#### *How to Spend Owners Money with No Return on Investment*

**F**rom a historical perspective, most engineers are taught that the use of a water to cement ratio (w/cmt) can be a design tool that is an implicit indicator of concrete performance. Unfortunately, the practical reality of using w/cmt for design is much less successful, is no guarantee of any actual performance, and in fact quite costly.

The w/cmt ratio is a simple mathematical relationship between the weight of water to the weight of cementitious material in a concrete mix design, not a measure of performance. The cementitious material includes the cement and any pozzolanic materials that are used as a replacement or in addition to the cement.

A specification that makes use of a w/cmt will state a maximum w/cmt not to exceed within the mix design. The idea is that by limiting the w/cmt, some performance characteristic such as compressive strength, shrinkage, or creep can be controlled. But since it is only a mathematical relationship between the weights of materials, it is only through assumption that a specification can hope to achieve certain levels of performance.

As an example, a standard commercial concrete specification may include the following requirements:

- $f'_c = 3000$  psi at 28 days
- Maximum w/cmt = 0.45
- Minimum cement content = 5.0 sacks (470 lbs.)
- Maximum Slump = 4 in.
- Maximum 1.5 in. aggregate

Based on the max w/cmt of 0.45, and the 470 lb minimum cementitious content, the maximum water content for the design can only be 212 lbs ( $0.45 \times 470 \text{ lb} = 212 \text{ lb}$ ). However, the question becomes, is 212 lb of water enough to generate a 4.0 in max slump? According to ACI 211 Chp. 6, Table 6.3.3 the water content for a 1.5 in aggregate, with a 3 to 4 in slump is 300 lb of water.

Assuming that a standard ASTM C494 Type A water reducer is used (8% water reduction) the required water content becomes 276 lb ( $300 \text{ lb} \times 92\% = 276 \text{ lb}$ ).

If the specified design only allows 212 lb and ACI states we need 276 lb, there is a 64 lb difference in necessary water content. A standard rule of thumb used in the field is that 1 gal/yd<sup>3</sup> of water will increase the slump by 1.0 in. In this case the 64 lbs is about 7 ½ gallons of water, thereby reducing the slump by about 7.5 inches. Essentially it makes the slump of the concrete 0 inches, if we followed the specified w/cm and used the minimum cementitious content.

Since this is not a practical concrete, then the question becomes, what choices are left to make it a concrete that can be produced, delivered, placed, and finished? If we use the water content of 276 lb, and keep the max w/cmt in place, the new cementitious content becomes 613 lb ( $276 \text{ lb} \div 0.45 = 613$ .) The original 470 lbs has now been increased by 1.5 sk/yd<sup>3</sup> to satisfy the w/cmt requirement.

So, in an effort to satisfy a w/cmt ratio that had no real basis in the performance of the structure, to meet the design requirements and practical delivery and placement issues, the following consequences result:

- The cost per yard will increase accordingly with a 1.5 sk/yd<sup>3</sup> increase.
- The concrete will be prone to higher shrinkage and creep with the higher paste content.
- The higher paste content will accelerate hydration and heat generation during warm and hot weather conditions, decrease finishing time, and intensify the potential for plastic shrinkage cracking.
- There is no guarantee of durability and more paste is subject to deterioration and chemical attack.

The attempt to use w/cmt to create durable and cost effective concrete can actually result in just the opposite. A more sensible approach is for the specifications to explicitly detail the performance characteristics, rather than assume they can be accomplished with a mathematical ratio.

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This position statement from the Texas Aggregates and Concrete Association is presented for reader interest by the editors. The opinions expressed are not necessarily those of the "magazine". Reader comment is invited.

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Texas Aggregates and Concrete Association  
900 Congress Ave., Suite 200  
Austin, TX 78701 Phone: 512-451-5100 FAX: 512-451-4162  
[www.tx-taca.org](http://www.tx-taca.org)

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