Specification in Practice

What, why & how?

SIP 5 – Restrictions on Aggregate Grading

by the NRMCA Research Engineering and Standards Committee

WHAT is the typical specification requirement?

The typical alternative clauses controlling the grading of aggregates in specifications are:

> The grading of the combined aggregate shall conform to the percent retained on individual sieves between 8 and 18% (or 6 and 22%), with the exception of the smaller and higher sieves.
>
> The Coarseness Factor and the Workability Factor determined from the combined aggregate grading shall be within the [required] Zone on the Aggregate Constructability Chart.
>
> The combined aggregate grading when plotted on a 0.45 power chart of the sieve size shall not deviate from a line drawn from the origin to the largest aggregate size within a tolerance of 2%.

These types of requirements are typically included in specifications for some conventional and industrial floor slabs, specifications of some state highway agencies for road pavements, and a specification for airport pavements (FAA 2014). In some cases, these are stated as general requirements for all concrete on a project. An NRMCA review of more than 100 project specifications found that about 25% of reviewed project specifications included requirements for combined aggregate grading.

DO industry standards have these requirements?

ACI 318-14 and ACI 301-10 require aggregate used in concrete to conform to ASTM C33/C33M. There are no requirements on the grading of the combined aggregate.

ASTM C33/C33M establishes grading bands for coarse aggregate based on size number and for fine aggregate.

ACI 302.1R-04 has suggested requirements on combined aggregate grading when proportioning concrete mixtures for floors. This is a non-mandatory guide and is not a specification.

WHAT is the basis for this specification requirement?

The coarseness factor chart was developed by Shilstone (1990). Coarseness factor (x-axis) is the percent of the combined aggregate retained on the No. 8 (2.36 mm) sieve that is also retained on the 3/8 in. (9.5 mm) sieve. Workability factor (y-axis) is the percent of the combined aggregate that passes the No. 8 (2.36 mm) sieve. In the 0.45 power chart, the y-axis represents the percent of the combined aggregate passing each sieve and the x-axis represents the sieve opening in micrometers raised to the 0.45 power.

ACI 302.1R-04 states that compliance with the combined aggregate grading specifications will increase aggregate packing, reduce the water demand, and lower the cement paste volume required to coat the aggregate. Some state highway agencies, such as Iowa and Minnesota, invoke aggregate grading requirements with the intent of reducing cement content, shrinkage, and cracking.

Research at NRMCA (Obla et al. 2007a, b; Obla and Kim 2008) found that combined aggregate gradings meeting the 8-18 and the coarseness factor chart requirements did not result in reduced aggregate void content and did not improve concrete performance through lower water demand, shrinkage, or higher strength. Based on experimental studies on Florida aggregates, McCall et al. (2005) concluded that concrete with combined aggregate grading meeting the 8-18 requirements did not yield lower water demand, drying shrinkage, or cracking. A study conducted for the Mississippi highway department (Varner 2010) concluded that optimized combined aggregate grading did not lead to concrete with lower shrinkage, chloride ion penetrability, or higher strength. Recently, Cook et al. (2013) and Varner (2012) have shown that the typical 8-18 and coarseness factor chart requirements did not lead to improved concrete performance, but did recommend modified limits on the individual percent retained for combined aggregate. Varner (2012) suggests that contractors be allowed to submit shrinkage data in lieu of combined aggregate grading requirements. The void content of combined aggregate determined in accordance with ASTM C29/C29M has been suggested as a tool for concrete mixture proportioning (ACI 211.6T-14; Yurdakul 2013; Obla 2012).

HOW can these requirements be restrictive?

- While conformance can be verified in a submittal, aggregate grading requirements cannot be verified and enforced during concrete production for a project. Grading of aggregate changes with transport and intra-plant handling;
- Factors other than aggregate grading impact workability and shrinkage. The intended performance may not be achieved and instills a false sense of security;
- Most concrete producers use two or three aggre-

gates to produce concrete and their ability meet the grading requirements may be constrained by the additional bin storage needed; and

- The grading of available aggregates in some markets makes it difficult to achieve the requirements without importing aggregates from distant sources.

WHAT is the alternative to this specification requirement?

- Use a performance-based option to determine the shrinkage potential of the concrete mixture: length change of concrete, determined by ASTM C157/C157M, with 7 days of moist curing followed by 21 days of drying shall not exceed 0.05%;
- Avoid specifying *w/cm* less than 0.40 for floor and pavement applications, because autogenous/chemical shrinkage, which can be a significant component of total shrinkage that occurs in the first 24 hours, will not be measured by ASTM C157/C157M;
- Specify demonstration of workability and handling characteristics of concrete through either past field history or through a trial slab as suggested in ACI 301-10; and
- Request aggregate grading and void content of the combined aggregate in the submittal.

Other fresh and hardened concrete properties can be ensured by specifying the applicable performance

WHAT is the benefit of this alternative requirement?

The performance-based alternative to determine the shrinkage potential of the mixture provides more assurance of reduced drying shrinkage than specifying aggregate grading. The concrete producer can use aggregate grading and other methods, such as the use of shrinkage reducing admixtures, to proportion concrete mixtures and achieve the specified shrinkage requirement.

Similarly, the finishability is ensured by a trial slab placement rather than specifying aggregate grading.

It is recognized that wide variations in the combined aggregate grading can affect concrete workability and hardened concrete properties. It is the responsibility of the concrete producer to monitor and control the grading of aggregates within reasonable target limits as part of their quality management system (Obla 2014).

The alternative permits the concrete producer to use locally available aggregates and avoid excessive investment in increasing storage capacity and bins for additional aggregates. This helps optimize costs and supports sustainability.

References

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