Cement Specification Emphasizes Performance

by Paul D. Tennis

ASTM C 1157, covering both blended and portland cements, moves away from requirements on chemical composition

ASTM C 1157, Standard Performance Specification for Hydraulic Cement, is a relatively new specification in which restrictions on composition of the material are minimized. For the producer, ASTM C 1157 allows optimal use of raw materials and the ability to produce innovative cements. For the specifier, it contains optional requirements that are not available under other specifications. Requirements in C 1157 are largely based on C 150 and C 595, the traditional, cement specifications that contain a combination of prescriptive and performance limits. However, the newer specification contains unique features as well.

ASTM C 1157 was first approved in 1992 as a performance specification for blended cements; however, in 1998 it was amended to include portland cements. Thus, for the first time, both portland and blended cements could be specified under one standard based on identical performance requirements. Cements are classified into six types according to their intended use: GU for general construction, HE for high-early strength, MS for moderate sulfate resistance, HS for high sulfate resistance, MH for moderate heat generation, and LH for low heat generation. An optional suffix, R, may be added to the cement type (for example, GU-R) if laboratory testing (C 227) indicates the cement is resistant to alkali-silica reactivity (ASR).

Focus On Performance

The new specification represents a shift away from prescriptive specifications that dictate composition restrictions. Instead, the emphasis is on the ability of the cement to perform. For example, in C 150, the tricalcium aluminate (C_3A) content in Type II or V cement is prescriptively limited to control sulfate resistance. In ASTM C 1157, assurance of sulfate resistance of Type MS or HS cement is determined by testing (C 1012) mortar bars made with the cement. The laboratory test, rather than a chemical analysis, is used as a predictor of performance.

Unique Strength Provisions

The strength provisions of C 1157 are an example of one of the unique aspects of the specification. By default, strength requirements are the minimums shown in Table 1. However, there are several optional requirements that can be invoked by the specifier, including an optional 28-day strength requirement, alternative (higher) minimums at specific ages, and strength ranges (within maximum and minimum values) applied at a specific age. Thus, if a specifier has an application requiring cement within a particular range of strengths, C 1157 provides an opportunity for invoking specific optional requirements to address that need. However, specifiers should be aware that cements may not be available to meet

Table 1. Default Minimum Strength Requirements of ASTM C 1157 (ASTM C 109), MPa (psi)

<table>
<thead>
<tr>
<th>Cement Type</th>
<th>1 day</th>
<th>3 days</th>
<th>7 days</th>
<th>28 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>GU</td>
<td>17 (2465)</td>
<td>10 (1450)</td>
<td>5 (725)</td>
<td>17 (2465)</td>
</tr>
<tr>
<td>HE</td>
<td>10 (1450)</td>
<td>17 (2465)</td>
<td>10 (1450)</td>
<td>17 (2465)</td>
</tr>
<tr>
<td>MS</td>
<td>5 (725)</td>
<td>10 (1450)</td>
<td>10 (1450)</td>
<td>5 (725)</td>
</tr>
<tr>
<td>HS</td>
<td>5 (725)</td>
<td>10 (1450)</td>
<td>10 (1450)</td>
<td>5 (725)</td>
</tr>
<tr>
<td>LH</td>
<td>10 (1450)</td>
<td>17 (2465)</td>
<td>17 (2465)</td>
<td>17 (2465)</td>
</tr>
</tbody>
</table>

Many limits in C 1157 applicable to all cement types are similar to requirements in C 150 and C 595. All cement types in C 1157 are required to meet maximum autoclave expansion (0.8%) and maximum mortar bar expansion (0.020% at 14 days) limits that are identical to those in C 150 and C 595. Likewise, initial setting time (Vicat test, C 191) is between 45 and 420 minutes, which is identical to C 595 and only slightly extended from C 150 (between 45 and 375 minutes). One optional requirement, that for early stiffening (C 451), is identical to an optional requirement in C 150. Unlike C 150 and C 595, C 1157 does not include requirements for air-entraining cement. Air content (C 185) and fineness (C 204) are reported for informational purposes, but have no specification limits.

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optional requirements and should check with their cement or concrete supplier to determine whether particular options are available in their area.

For sulfate-resistant and controlled-heat-of-hydration cements, requirements are based on performance tests with limits again similar to those in C 150 and C 595. For example, Type MH cements are required to generate (C 186) less than 290 kJ/kg at 7 days, matching optional requirements for low heat Type II in C 150 and the MH option in C 595. Type LH cements are required to generate less than 250 kJ/kg at 7 days and less than 290 kJ/kg at 28 days, identical to the requirement for equivalent types in C 150 (Type IV) and C 595 (LH option). Requirements for Type MS cements, maximum expansion (C 1012) of 0.10% at 180 days, are similar to optional requirements in C 150 for Type II and for optional sulfate-resistant cement in C 595. Type HS cements have more restrictive requirements based on C 1012: 0.05% at 6 months, or 0.10% at 1 year.

In summary, many ASTM C 1157 performance requirements are similar to those in the more traditional C 150 and C 595 specifications. However, options for specifying cements with particular properties that cannot be specified elsewhere are also included. This brief review cannot cover all provisions of the standard; readers are encouraged to carefully examine the specification for complete details. ASTM C 1157 can be ordered from ASTM’s Web site at www.astm.org, or by calling 610.832.9585.

A common finding of the above research is that all deicers can aggravate scaling, emphasizing the need for placing high-quality, air-entrained concrete in deicer environments.

References


Concrete in a Marine Environment

Seawater contains significant amounts of sulfates and chlorides. Although sulfates in seawater are capable of attacking concrete, the presence of chlorides inhibits the expansive reaction that is characteristic of sulfate attack. Calcium sulfoaluminate, the reaction product of sulfate attack, is more soluble in a chloride solution and can be more readily leached out of concrete, thus resulting in less destructive expansion. This is a major factor explaining observations from a number of sources that the performance of concrete in seawater with portland cement having tricalcium aluminate (C₃A) contents as high as 10%, and sometimes higher, have shown satisfactory durability, providing the permeability of the concrete is low and the reinforcing steel has adequate cover.

The maximum permissible water-cement ratio for the submerged portion of a structure is 0.45 by weight. For portions in the splash zone and above, the maximum permissible water-cement ratio is 0.40 by weight. Water-cement ratios as high as 0.50 by weight may be used provided the C₃A content of the cement does not exceed 8%.

Cements meeting the requirements of ASTM C150, Specification for Portland Cement, and ASTM C595, Specification for Blended Hydraulic Cements, and meeting the C₃A requirement noted above, that is, not more than 10%, are acceptable for concrete in a marine environment. In the case of C595 blended cements, this limitation applies only to the Portland cement clinker used in the blended cement.

In addition to the proper selection of cement and water-cement ratio, other requirements for securing economical and durable concrete in a marine environment include: (1) adequate air entrainment, (2) low slump, (3) adequate consolidation, (4) uniformity of batching, mixing, transporting, and placing, (5) a smooth finish free from surface voids and other defects, (6) adequate concrete cover over reinforcement [minimum 2 in. (50 mm), preferably 3 in. (75 mm)], and (7) sufficient curing to develop the required impermeability and other desired properties of the concrete.

For More Information

Performance Standards are Coming


Unique Development
Unlike C595, the new C1157 performance standard does not dictate the composition or constituents of blended cement other than the requirement that it should consist of “two or more inorganic constituents which contribute to the strength-gaining properties of the cement, with or without other constituents, processing additions, and functional additions.” The blended cement...
may be produced by intergrinding or other blending processes. C1157 does require that the ingredients of the blended cement be reported and that the ingredients, including processing and functional additions, independently meet any applicable specifications.

“This really is a unique development,” notes Steven Kosmatka, who as PCA’s manager of research and development tracks specifications and standards in the cement industry and serves on several ASTM committees. “For the cement industry, it’s our first foray into performance specifications.”

Six Types

C1157 sets physical requirements for the following six types of blended cement, mirroring the attributes of ASTM’s C150 cement types:

- **Type GU**—Blended cement for general construction use when a specialized type is not required
- **Type HE**—High Early Strength
- **Type MS**—Moderate Sulfate Resistance
- **Type HS**—High Sulfate Resistance
- **Type MH**—Moderate Heat of Hydration
- **Type LH**—Low Heat of Hydration

In addition, any of the above types may be designated with Option R—Low Reactivity with Alkali- Reactive Aggregates. If Option R is invoked, the cement should be tested using ASTM Test Method C227, which uses crushed borosilicate (Pyrex) glass as the reactive aggregate. The expansion during this test should not exceed 0.020% at 14 days or 0.060% at 56 days. Additionally, pozzolans used in any blended cement also should be tested using C227 with a nonreactive sand to determine whether they have any potential for alkali-reactivity.

Optimizing Cements

As noted earlier, the new standard does not replace ASTM’s existing C595 standard; the new designations for six types of blended cement are simply an additional way to specify blended cements. “It gives cement companies far more leeway in formulating their product,” concedes Kosmatka. “For the first time, manufacturers can truly optimize cements, using ingredients available to them without the limitations of recipe specifications.”

Ultimately, performance-specified blended cements could spawn a new breed of products—special formulations that address specific customer needs such as resistance to alkali-aggregate reaction and sulfate reaction, to name two.

There are also environmental considerations. Blending portland cement with materials such as fly ash, ground granulated blast-furnace slag, kiln dust, or limestone means less embodied energy and reduced carbon dioxide emissions. And in the case of kiln dust, slag, fly ash, and other mineral byproducts, it’s a way to recycle waste materials into cement.

Acceptance?

But don’t expect an overnight shift from recipe to performance specifications; publication of the standard is only the beginning. It has yet to be accepted by ASTM C94 Specification for Ready-Mixed Concrete, the ACI 318 Building Code, ACI 301 Specifications for Structural Concrete for Buildings, and other important standards and codes organizations, a process that could take the rest of this decade. Moreover, acceptance may be only the first hurdle. Historically, U.S. specifiers have shied away from blended cements, perhaps finding a tandem set of cement types confusing. Adding a third set—C1157—to the existing C150 and C595 specifications may further complicate cement choices.

In any case, if use of a blended cement under ASTM C1157 is contemplated, or an order is placed, a request should be made for the manufacturer’s certification, which is discussed in Section 14 of the standard. This section requires the manufacturer to provide results of tests and chemical analyses and a list of specific constituents and functional additions, if any, contained in the cement specified.