Concrete Technology Advancements: New Tests and the Performance Engineered Mixture Specification

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For a number of years, the Federal-Aid Highway Program has been moving in a performance-based direction, seeking to link program- and project-level criteria with the results obtained. This was formalized in the MAP-21 (Moving Ahead for Progress in the 21st Century Act) legislation and has continued with the Fixing America's Surface Transportation Act. While this move toward performance criteria for the highway program has been on a programmatic level, concrete materials technology has moved in a similar direction. Recent developments in concrete technology have, for the first time, made it possible for highway concrete to be specified with a performance specification and for meaningful upgrades to take place with quality-control (QC) processes and programs.

PEM and What It's About

American Association of State Highway and Transportation Officials (AASHTO) recently published provisional specification PP 84-17, *Standard Practice for Developing Performance Engineered Concrete Pavement Mixtures*, known as the performance engineered mixture (PEM) specification. This specification is the result of a multiyear collaboration among the Federal Highway Administration (FHWA), state departments of transportation, researchers, and industry.

The underlying concept behind the PEM specification is to understand what makes concrete last and what failure mechanisms affect concrete durability. Then critical properties are specified and mixtures are designed to meet the required level of performance. Finally, testing is done on those critical properties, both as a QC function by the contractor during production and as an acceptance function by the agency.

The following six performance areas are identified as critical to durable in-service concrete:

- Strength
- Reducing unwanted cracking due to shrinkage
- Hardened cement paste freeze-thaw durability
- Transport properties (permeability)
- Aggregate stability
- Workability

In the AASHTO PP 84-17 specification, each of these properties has a table intended to guide the user in selecting the appropriate criteria to incorporate into a specification. Specifiers can choose which performance parameters they want to include into their specifications, with the understanding that not all owners may be willing to move to a complete performance specification right away. It is significant that while the title of the specification denotes applicability to concrete roadway paving, the concepts are nearly all directly applicable to structural concrete as well.

Durable Concrete Properties

The AASHTO PP 84-17 specification is flexible and can be tailored to the needs of the specifier. There are various performance and prescriptive options for many of the critical properties and tests. In addition, guidelines for each test are included, such as whether the test is used as a mixture qualification test, as an acceptance test, or both. Selected highlights for each property are as follow:

- Strength: In-service concrete rarely fails due to poor strength. This section of AASHTO PP 84-17 mirrors the common practice of specifying either compressive or flexural strength.
- Reducing unwanted cracking due to shrinkage: For specifiers who want to retain a prescriptive approach to shrinkage, the specification suggests a maximum volume of paste. The performance approach lists several options for assessing shrinkage, including a dual ring test that is being developed as an AASHTO standard test.
- Hardened cement paste freeze-thaw durability: Freeze-thaw durability is addressed with the prescriptive option of specifying a maximum water-cement ratio. The performance approach has several options, including using the super air meter (SAM) (AASHTO TP 118) in lieu of the traditional Type B pressure pot (AASHTO T 152). The SAM is a new test that offers the significant advantage of providing information

Compared to traditional test methods, the super air meter provides a better indication of concrete's ability to resist freeze-thaw damage. All Photos: Federal Highway Administration.

The Federal Highway Administration's mobile concrete trailer assists states across the country with implementing new concrete technology.

on the air-void system in the concrete, not just the total amount of air. The specification also includes guidance on the use of supplementary cementitious materials to address calcium oxychloride formation, a by-product of the use of modern deicing chemicals.

- Transport properties (permeability): For this property, specifying a maximum water-cement ratio is a prescriptive approach. Options for specifying performance include the rapid chloride permeability test (AASHTO T 277) or the surface resistivity test (AASHTO TP 95), either of which could be incorporated as part of the determination of the formation factor of the mixture. The formation factor is the subject of ongoing research by Dr. Jason Weiss at Oregon State University that links the electrical conductivity of the concrete mixture with its pore chemistry.
- Aggregate stability: The specification for this property includes standard methods for determining vulnerability to D-cracking (AASHTO T 161) and to alkali-silica reactivity (AASHTO PP 65).
- Workability: The slump test does little to inform specifiers about the durability or performance of a concrete mixture. It is merely an indication of workability, but does not consider how modern mixtures perform during consolidation. AASHTO PP 84-17 takes this into consideration by including the new box test and the V-Kelly test, which are better able to assess how the fresh concrete responds to vibration and are far better indicators of the workability of the concrete. The box test and V-Kelly are specifically for slip-formed concrete pavements. Similar concepts are being used to develop a test for structural concrete. This test, referred to as the float test, provides an indication of the finishability of structural flatwork concrete.

Quality Is Key

Performance specifications shift some risk and control to the contractor. With agencies retaining responsibility for maintaining the finished product, the traditional project oversight role needs to shift to one that is more appropriate in a performance-specification environment.

With a performance specification, the contractor's QC plan details much of how the concrete will be produced and placed, rather than relying on traditional method specifications. Agencies will need to take an increased role in approving the QC plan and overseeing its use on the project. In addition to the performance properties and associated selection tables, the PEM specification includes language regarding contractor QC testing and requires QC testing and control charts for both traditional and cutting-edge tests.

Implementation Underway

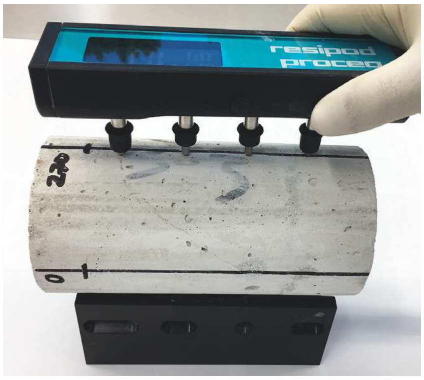
Implementation efforts are vital to moving agencies toward a performance specification for concrete. Training on new tests, user-friendly testing guides including suggested testing frequencies, and hands-on education are planned. FHWA's mobile concrete trailer has been using the tests included in AASHTO PP 84-17 for the past year and is planning to travel to state agency projects to pilot or shadow the usage of the specification. Good collaboration between public agencies and contractors is important for successful implementation of performance specifications. To meet this need, FHWA will work to include guidance for contractor quality-control processes under a performance specification.

Conclusion

Recent advancements in concrete technology have paved the way for the implementation of performance specifications. AASHTO PP 84-17, *Standard Practice for Developing Performance Engineered Concrete Pavement Mixtures*, when used in conjunction with other tools to optimize the materials in concrete mixtures, offers the ability to characterize concrete in ways that were not possible previously. It is also now possible to develop meaningful upgrades to contractor/supplier quality-control programs, which will ensure that more consistent concrete is produced. The FHWA remains committed to working with stakeholders to continually improve and advance PEM into widespread implementation. Ultimately, the FHWA is striving for a more durable, sustainable, and economic concrete, ensuring a longer service life benefitting taxpayers and the driving public.

EDITOR'S NOTE

For more information, click on the Resources tab at www.aspirebridge.org for links to two presentations on performance mixtures.



The surface resistivity test is a quick and repeatable nondestructive test that provides an indication of the concrete's ability to resist chloride intrusion.

The box test evaluates how a concrete pavement mixture responds to vibration and provides a more accurate assessment of workability than the slump test.