Performance Cements Webinar Q&A

August 8, 2023

1. We talk about compressive strength with performance cements in concrete, but what about things like shear strength?
   Shear strength (and direct tensile strength) of plain concrete is rarely tested. Engineers typically care more about shear or flexural capacity of a reinforced concrete element in a structure. While the strength of the concrete in those elements is important, the performance is also substantially influenced by the reinforcement used in the element.
   Flexural strength of plain concrete is often specified for pavements and project specifications may either require establishing a relationship between compressive and flexural strength for the proposed mixture, and testing of compressive strength during construction, or simply testing of flexural strength of plain concrete beams (per ASTM C78) to demonstrate compliance with specifications.
   When other mechanical characteristics (such as creep, shrinkage, elastic modulus, etc.) of the concrete are critical to a specific project requirement, it can be necessary to test them as well to obtain approval of the proposed concrete mixture. These tests are all more complex and typically more costly to perform, so they are generally not performed unless necessary for a project. The ASTM C109 mortar cube compressive strength testing in most cases will serve as a sufficient quality check on the cement itself, but it is not intended to represent how all possible mix designs incorporating that cement will perform. [*PCA*]

2. For your testing charts comparing the 1L(10) and 1L(20), how many tests were done in each group to get the averages? Thank you.
   For 100% Blended cement testing in concrete (no admixtures), we completed three different evaluations which provided similar results. The testing charts included within the presentation is using one set of data which was the actual cement we used for the MnROAD project. [*Continental*]

3. What was the design strength of the 1L(10) and IL(20) mixes? Also, what class of fly ash was used?
   The 100% blended cement concrete mixtures is designed for 5,000 psi non-air entrain mix and does not use any fly ash (this mix would be 4k psi with air entrained). The same concrete design was used for both IL(10) and IL(20) concrete batches.
   For the Iowa DOT C-3WR-C20 concrete mix, the designed strength was 4,000 psi and used 20% Class C fly ash from Muscatine, Iowa. The concrete was batch similarly with IL(10) and IL(20) cements with no changes to any materials or admixtures. [*Continental*]

4. Over previous C150 mixes, did these mixes IL (10) and (20) requires higher amounts of concrete admixtures, i.e. WR.
   Observations of admixture dosing requirements are based on results from Iowa DOT C-3WR-C20 concrete mix. All concrete was batched at w/c 0.43, 0.65 oz/cwt AEA and 3.0 oz/cwt of MRWR.
   C150 vs. C595 Comparison (2022)
   C150 Type I/II (control) – Slump 3.75", Air content 6.9%, Air void structure sufficient for durability
   C595 Type IL(10) – Slump 3.50", Air content 6.3%, Air void structure sufficient for durability
   C595 vs. C1157 Comparison (2023)

C595 Type IL(10) – Slump 4.00”, Air content 5.5%, Air void structure sufficient for durability
C1157 Type IL(20) – Slump 4.25”, Air content 6.2%, Air void structure sufficient for durability
[*Continental*]

5. Nicolas, the 28 to 56-day strengths shown between the IL (10) and IL (20), would you consider that an adequate increase in strength?
   Yes, I would consider the strength development from 28 day to 56 day to be typical and expected. This was evident in evaluating the comparative strength gain performance of the concrete mixes shared during the presentation.
   % Increase in concrete compressive strength from 28 days to 56 days
   C150 vs. C595 Comparison (2022)
   C150 Type I/II – 5.2%
   C595 Type IL(10) – 5.1%
   C595 vs. C1157 Comparison (2023)
   C595 Type IL(10) – 2.3%
   C1157 Type IL(20) – 8.0%
   [*Continental*]

6. Comment and Question - Durability is a concrete problem. It really makes no sense to think of durability of cement only. The cement needs certain properties to make good concrete such as strength, set time, sulfate resistance, and the ability to entrain air. These are aspects to measure if determining if a cement will perform to make durable concrete. What else could be measured, in your opinion?
   I agree that the concrete is the final product and really needs the durability. But, TRB Ecircular E-C171 on durability of concrete notes ”Serving as the binding matrix of concrete, the chemical and physical stability of the paste phase, as well as its microstructure, are critical to the durability of the concrete.” And as a former Materials Engineer I also dealt with asphalt- in asphalt they do measure the binder for durability by laboratory aging it and testing. I consider the mortar bar expansion test (C1038) to be somewhat of a durability test, but feel more are needed to cover other areas of durability for cement (shrinkage, resistance to water, reaction with other chemicals, freeze-thaw, abrasion, etc.) - potentially using mortar bar samples?
   [*GGfGA*]

   Test methods related to cement impacts on durability are largely similar in the various specs and depend on the exposure/durability situation asked: For sulfate resistance, C150/M 85 defaults to prescriptive C3A content limits while C595/M 240 and C1157 refer to C1012 testing. For corrosion resistance, concrete permeability dominates, but chloride contents of cements can be reported. For ASR resistance, C150/M 85, C595/M 240 require reporting of data needed to utilize C1778 (AASHTO R 80) guidance. For freeze-thaw, concrete air content dominates the performance, and the cement has little impact.
   It is important to note that tests of the cement generally help understand how the cement will contribute to the durability characteristics of concrete made with it, however, they are not intended to prove that a particular concrete mixture will have a certain performance. SCMs in a concrete mixture, the w/cm, and admixtures in a concrete mixture can be optimized to achieve the necessary durability performance and the mix design as a whole often must be tested to

demonstrate this in order to approve its use on a project. It may be appropriate to consider tests of the complete binder system as more critical than tests of the cement when designing a concrete mixture for given project requirements. [*PCA*]

7. If new cements are to be tested in the FHWA program you mentioned, how will they be specified if we do not recognize C1157?
   I did not mean to imply that C1157 should not be used at all, I believe it can be used for pilot tests for new cements, to get us to the comfort level of including them in M 85/C150 or M 240/C595. States can allow C1157 (or simply allow M 85 or M 240 and waive the chemical requirements) for pilot/testing purposes. But C1157 is so open (it is essentially M 85/C150 or M 240/C595 without the chemical testing requirements) that allowing a C1157 cement in the Standard Specifications will negate those conventional standards and may provide unknown consequences. [*GGfGA*]

   This is a concern. In the near term, the use of special provisions to permit C1157 cements for demonstration projects may be suitable as a first step. In the longer-term, PCA would recommend permitting all three national specifications for cement (C150/M 85, C595/M 240, and C1157) to be referenced in state and project specifications, and letting concrete producers work with their cement suppliers to provide the best source for a given application, considering durability, structural performance, and sustainability. All of these specs are recognized by ACI 301, ACI 318, etc. and International Code Council documents. We encourage input on ways to improve C1157 through the ASTM standardization process to resolve user concerns. [*PCA*]

8. Comment and Questions - We heard excellent talks by PCA, Continental Cement, and Georgene Geary, but the latter had a very different perspective as a representative of the owner. The planet we are living on just had the highest recorded July on record and the continued warming is strongly linked to human influenced climate change…most notably greenhouse gas (GHG) emissions that have been steadily climbing since the beginning of the industrial revolution. The production of portland cement is CO2 intensive, being responsible for roughly 0.92kg CO2eq/kg of cement produced in the U.S. The only lever a cement company has to lower the carbon footprint of their product is to lower the clinker content by selling blended cements. Continental Cement discussed the promise of their Type IL(20), not specifically mentioning that the concrete made with their cement blended with 30% Coal Creek Class F fly ash at MnROAD had the highest strength and lowest permeability of any the other concretes placed. This material, or a similar limestone calcined clay cement (LC3), cannot come to market without a performance specification such as ASTM C1157. My questions to each speaker are:

   a. How can state highway agencies (SHAs) embrace change and adopt lower clinker, lower carbon binders recognizing that 1) these binders are different from what they are used to using, and 2) with change comes risk?
      The LinkedIn article I mentioned noted that cements do react differently with different materials. Producers need to recognize this and recognize that DOTs must do their due diligence to protect the public’s investment. I think risk needs to be shared, and producers can help embrace change by being involved in the testing (like the testing that was shown by Nicholas with the Iowa material and the MnROAD testing). [*GGfGA*]

Cement producers are working on many levers to reduce embodied carbon including increase in alternative fuels, transition to renewable energy as well as reduction in clinker factor including the expansion of blended cements.
SHAs can embrace this change by updating standards to include C150, C595, and C1157 standard specifications which are currently permitted in ACI and other standards. Secondly, State agencies should also take a proactive approach to work with cement and concrete producers to conduct trial and test pours to begin evaluating product performance (ex. MnROAD). It is important to note that the concrete structures in place >10 years in the US today were placed under a C1157 specification and provided the necessary information and experience to transition the market to PLC including updates to C595/M240 Standard specifications. Lastly, I believe it is imperative that all SHA and engineers stay abreast of the changes to cement and concrete specifications and search out updates to trials being completed in other SHA and countries.
While risks exist in all projects, C1157 cements are manufactured to achieve strength and durability requirements. Risks can be mitigated through comparative testing in placed concrete structures using C595 cements and C1157 cements to evaluate long term durability and strength performance. It is through these approaches that SHA can begin to meet sustainability goals, gain experience with sustainable products, and implement changes to SHA Standards for full adoption moving forward. [*Continental*]

Although lowering of clinker content is not the only lever for reducing a cement's GWP(see PCA's Roadmap to Carbon Neutrality: https://www.cement.org/docs/default-source/roadmap1/pca-roadmap-to-carbon-neutrality_final.pdf , it is a significant one. A primary goal of national standard cement specifications is to address the needs of all of the stakeholders involved: cement producers, concrete producers, specifiers, contractors, and owners, so referencing the national standard specs as options will help. Some hesitation in using novel materials is understandable, but some risk is necessary in response to climate change. For cements new to a specifier, trial batching to assure fresh and hardened concrete properties should go a long way to answering any questions, and additional studies like the those that the MnROAD facility has been conducting for years should be encouraged. [*PCA*]

b. Please offer specific actions needed to overcome the institutional inertia that Georgene spoke of.

First- be clear in what you want: I believe that there is a big difference between a Type IL(20) {that is really just an extension of Type IL(15)}, and, what other materials a producer could make that meets C1157 (like the w/c of 0.23 example I used). C1157 is not the panacea and I fear it could cause problems that would take us backwards if it is used and sold that way. Second- let's have a discussion on how to test or specify cements that provides some level of certainty that we will get consistent, durable concrete (yes, I meant concrete) and what research we need to answer these questions. [*GGfGA*]

Specific actions:

i. Update SHA Standard/Specifications to permit the use of C1157 Cements
ii. Target which products the SHA would like to target (higher limestone content PLCs, slag blended cement, pozzolan blended cement, etc.)

iii. Collaborate with cement and concrete producers in addressing concerns of SHA in order to accelerate information flow and increase confidence level and eliminate misconceptions
iv. Identify lower risk projects to begin using C1157 cements to evaluate performance
v. Share learnings with other SHA, identify larger projects for integration

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