Optimizing Concrete with Pozzolanic Reactivity

For over 25 years, the ACI Foundation has hosted forums to support the concrete industry's adoption of innovation. These events provide educational and networking opportunities, featuring presentations by researchers, ACI committee representatives, and developers of new technologies. This article highlights a presentation from the 2025 Concrete Innovation Forum, "Using Pozzolanic Reactivity to Optimize Concrete Mixtures for Performance, Cost, and Sustainability," developed by W. Jason Weiss, FACI, Edwards Distinguished Chair in Engineering, Oregon State University (OSU), and Burkan Isgor, FACI, Professor of Civil Engineering and Materials Science, OSU. Delivered by Weiss, this presentation focused on combining science-based tests with rigorous computational models to help design concrete mixtures for the future.

Shifting the Focus in Concrete with Lower Clinker

The presentation began with a message by Weiss: to achieve low-global warming potential (GWP) concrete mixtures, the industry must fundamentally examine many of its testing methods, focus on placement and curing practices, and update specifications. He illustrated that the largest contributor to concrete's GWP is cementitious materials. New and promising cement technologies are emerging; however, the industry remains reliant on systems that are fundamentally based on portland cement clinker and likely will for the coming decades. Moving to different industrial-scale solutions is a massive undertaking due to the required volume and the heavy investments already made in existing clinker-based infrastructure.

He argued that the industry's current focus on Environmental Product Declarations (EPDs), only accounting for A1-A3 GWP (from raw material supply to manufacturing), often overlooks the life-cycle performance. Weiss provided an example that a bridge designed to last 90 years instead of 22 years offers a profound sustainability benefit even if its initial GWP is the same or slightly higher as a conventional structure. Focusing only on the A1-A3 GWP values misses the bigger picture, as concrete durability is one of its greatest attributes.

Another key to sustainability is optimizing mixture designs. Weiss pointed out that many concrete mixtures are "over-cemented" for historical reasons, including the desire for a one-size-fits-all mixture design and a producer's risk avoidance for low compressive strength. Removing minimum cement content requirements from specifications has been a critical step that many groups have been taking over the last two decades toward more efficient and sustainable concrete.

Understanding and Using SCMs Correctly

The core of the presentation focused on reducing clinker content by using alternative supplementary cementitious materials (SCMs), including calcined clays and natural pozzolans. Weiss emphasized that these are not new or unproven materials, as structures built with them 80 years ago still perform well.

To use SCMs effectively, he identified five key properties that must be understood:

- Chemistry: Knowing the exact chemical composition allows for predictable reactions;
- Reactivity: Quantifying how reactive an SCM is using the pozzolanic reactivity test (PRT) provides a scientific number to work with, moving beyond subjective indices;
- Water Absorption: Many SCMs are porous and absorb water. This absorption should not be counted in the water-cementitious materials ratio (*w/cm*), a common mistake that negatively impacts workability, and should be accounted for in many specifications;
- Specific Gravity: Replacing cement by mass instead of volume alters the mixture and can negatively affect workability. A volumetric replacement maintains a consistent liquid-to-solid ratio, resulting in a workable mixture; and
- Particle Size Distribution: Optimizing the mixture proportions to predict water demand and reducing the amount of paste needed.

Weiss demonstrated that the workability and performance of concrete with alternative SCMs become more predictable and consistent when these factors are correctly accounted for, more closely matching traditional cement systems.

He also noted that trial batches are essential to understanding how changes in cementitious components may impact the workability, finishability, and hardened properties of concrete.

A New Era of Computational Tools

Mathematical models have been used in cement and concrete sciences for over a century. A significant portion of the discussion was dedicated to a computational tool developed at OSU over the last decade. This tool uses kinetic, thermodynamic, and pore partitioning modeling to predict concrete mixture performance with virtually any type of SCM. By inputting the chemistry and reactivity of the materials, the model can simulate the hydration products and predict properties such as strength, porosity, elastic modulus, and various durability indicators (for example, alkali-silica reaction [ASR], freezing-and-thawing resistance, and sulfate attack).

This computational approach allows for thousands of virtual trial batches to be run overnight, providing estimates of 90-day or even 365-day data almost instantly. This enables optimization, not just for performance, but also for cost, material availability, and carbon footprint. The tool can identify a "zone of feasible mixtures" that meet multiple criteria, providing engineers with an ideal starting point for physical trial batches.

Using the model, Weiss addressed a common misconception. While many believe SCMs reduce porosity, his simulations show that porosity often increases slightly. However, transport properties (like chloride resistance) improve dramatically. This is because SCMs refine the pore structure, creating a more complex and tortuous path that slows the ingress of harmful substances. This is a critical distinction between "pore refinement" and simple "porosity reduction."

A Call for Coordinated Research and Better Standards

Weiss concluded with a vision for the future. He called for a more coordinated research effort to avoid redundant, state-by-state testing of the same materials. He stressed the need to update specifications to align with modern concrete mixtures. Using existing specifications for modern cements and concretes can be analogous to using a rotary phone manual to operate a modern smartphone.

Key areas requiring immediate attention include:

- Fresh Properties: Developing a better scientific understanding of workability, bleeding, and finishability for modern concrete mixtures;
- Better Tests: Providing contractors with improved tests to understand the material they are working with, and to better articulate their needs beyond simple slump measurements;
- Databases for Modelers: Creating shared databases so computational models can be validated against real-world systems; and
- Contractor Feedback: Incorporating feedback from the field to ensure lab tests and simulations accurately reflect on-site performance.

Weiss's presentation was a call to action for the concrete industry to embrace science-based specifications, leverage modern computational power, and understand the materials being used to build a more durable and sustainable future.

2026 Concrete Innovation Forum

Save the date for August 18-20, 2026, to attend the 2026 Concrete Innovation Forum at the Hyatt Regency in Columbus, OH, USA. At this event, industry leaders, researchers, and innovators will share more advancements and practical solutions for the future of concrete. This is an opportunity to connect, learn, and be inspired. In the meantime, the ACI Foundation will provide more articles in subsequent issues of *CI* to highlight presentations and insights from the 2025 Concrete Innovation Forum.

Acknowledgments

This article was developed by ACI Foundation staff from a presentation given by W. Jason Weiss on August 13, 2025, at the 2025 Concrete Innovation Forum. ACI Foundation staff used Jasper.ai to help summarize the presentation, then carefully reviewed the summary to develop this article. The ACI Foundation claims full responsibility for the content of the article.

Oreo Cookie Test

Weiss encouraged an alternative to the slump test for determining the rheology of a concrete mixture, which has been used in cement sciences for several decades. "What is the proper way to eat an Oreo cookie? Everybody knows you don't break it in half; you go for the crème filling. You apply a torsional force that will exceed the yield stress between the creamy filling and the shell. The same can be done for cement paste. You can put the paste between two serrated plates and start to twist them. The measured resistance to the twist is called yield stress. The resistance to the paste flowing is the viscosity. The first measurement tells us how hard it is to get the material flowing, and the second number indicates how hard the material is going to be to keep it flowing, like through a pumpline. Measuring the yield stress and viscosity provides a much clearer picture of a mixture's fresh properties."