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Research Results

PPRC23: Further development towards implementation of likely supplementary cementitious materials (SCMs)

Caltrans is always studying how to make our State Highway System more sustainable. The Department recently partnered on an innovative concrete study with the University of California Pavement Research Center (UCPRC) to test Alternative Supplementary Cementitious Materials (ASCMs). ASCMs have the potential to make highway concrete more resilient while lowering its carbon footprint!

Pavement

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WHAT WAS THE NEED?

Portland cement is a key ingredient in concrete. It's also a major source of greenhouse gas (GHG) emissions. In fact, Portland cement production accounts for approximately 10% of total global carbon dioxide emissions. Here in state, our California State Highway System uses concrete extensively. For example, concrete is used in various ways across one third of Caltrans' lane miles and in 90% of its structures such as bridges and retaining walls.

This also means even small improvements to concrete formulas add up and can have big impacts across the larger State Highway System. As an example, some material supplements can partially replace Portland cement in concrete mixes, reducing GHGs and enhancing mix strength; but nearly all standard supplements must be imported to California. And that creates both supply issues plus additional GHGs.

In some cases, potential solutions may already be available in California! ASCMs are generally abundant right here in California, so maybe they could replace standard cement supplements? Plus, many of them are natural materials like glass waste, wood ash, clays, even rice hulls and walnut shells! This made ASCMs important materials to test for potential usage in Caltrans' approved concrete mixes.

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WHAT WAS OUR GOAL?

The goal of this research was an evaluation of ASCMs to determine whether they could partially replace Portland cement. This included a technical report with ASCM test findings and roadmap for even more advanced testing and potential real-world use.

WHAT DID WE DO?

The UCPRC research team began by collecting more than 64 ASCMs —such as plant based ashes, biochar, natural minerals, and construction waste like rock dust, and even pond sludge! They then put each material to the test to learn more about their structure, composition and other characteristics. This included checking chemical composition using X ray tools, particle size and density, as well as microscopic closeups to get a clearer picture of each material's basic structure.

Next, they ran a series of tests to gauge how each material might work in real world conditions. Researchers started by replacing 20% of the Portland cement in small mortar cubes with one ASCM each and measured their respective strength at 7, 28, and 90 days. They also tested them exposure to heat and chemicals to see how they breakdown or if the sample performed as normal cement would be expected. In addition, they tested if the materials prevented cement from damaging expansion, had freeze/thaw durability, and how much water was used.

Finally, they evaluated and compared each material based on multiple criteria. Only the ASCMs that achieved the key performance goals—such as having strength similar to Portland cement and showing that they'd work well in concrete—were recommended to advance to the next phase of testing. They also advised about future sampling, supply evaluations, and updates to Caltrans specifications so that only the most promising materials move forward.

WHAT WAS THE OUTCOME?

The study recommends multiple ASCMs advance to the next stage of concrete-phase testing, including 15 biomass ashes, a few biochars, 28 natural pozzolans, rock dust from asphalt plants, and minimally ground wash pond sludge. These promising materials could help Caltrans produce durable and lower carbon concrete with readily available, locally sourced materials already found in state. The researchers did not recommend materials with consistently low performance such as recycled concrete and other construction waste.

The study also recommends determining more precise statewide/regional ASCM availability, plus volumes of these materials needed to replace standard cement supplements. And finally, the research team provided updates to supplement/ ASCM testing procedure including a higher strength requirement and assessment of how well a material actually prevents concrete cracking rather than generally dismissing it based on its chemical composition.

WHAT IS THE BENEFIT?

This research supports Caltrans' use of durable low-carbon concrete. That's because it evaluated promising natural ASCMs that are abundant right here in California! This will reduce the State's reliance on Portland cement and problematic standard supplements, while reducing concrete's overall carbon footprint. That will advance statewide climate goals and strengthen the California State Highway System's long-term resilience.

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