

Two Percent Cement

A unique concrete mix wins ASCE innovation award.

By: Joe Nasvik



The first use of this mix was AET's new High Energy Radio Graphic Testing vault. The walls are 3 ft. thick and the roof 2 1/2 ft. thick. The highly fluid mix was easy to pump and consolidate.

Credit: American Engineering Testing Inc.

A new concrete mix that combines recycled materials with a tiny amount of portland cement is this year's winner of the American Society of Civil Engineers' (ASCE) Charles Pankow Award for Innovation. The team that developed this concrete, and was presented with the award, was St. Paul, Minn.-based American Engineering Testing Inc. (AET), and Cemstone, Mendota Heights, Minn.

Developing the mix

The mix these companies developed features 2% portland cement—82 pounds in a 3875 pound/cubic yard mix. The rest of the mix consists of fly ash, slag, crushed recycled concrete for both coarse aggregate and sand, recycled concrete water, and admixtures. The air-entrained mix, with a water-cement (w/c) ratio of 0.45, attained an ultimate compressive strength exceeding 4000 psi and reasonable early strength.

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Since 2007, Cemstone Products has worked with AET to progressively create a mix design that uses the largest practical amount of recycled materials. They started with mass concrete mixes, designing a mix with supplementary cementitious material (SCM) to control heat generation. In the construction of AET's X-ray vault—a 3-foot-thick structure completed and put to use in 2008—the mix included additional recycled materials, such as reclaimed water and aggregates from recycled concrete. A somewhat modified mix was later used for construction of several bridges.

The developers wanted to create a high-performance mix that used as much recycled material as possible. They recognized crushing used concrete made with high-quality aggregates and using it solely as coarse aggregate was shortsighted. They also knew that using higher percentages of SCM results in slower strength development, although that can be a positive characteristic for mass concrete. The mix they developed actually performs better than concrete made with virgin materials, even though ACI 318 does not recommend greater than 50% substitution of

SCM for cement in concrete for severe exposure.

Credit: American Engineering Testing Inc.

Insights

Key innovative procedures and insights include:

Microscopic analysis of recycled concrete aggregate indicates there is always unhydrated cement available to form cementitious paste in the new mix.



- When recycled aggregates were used for this project, the companies included the entire gradation, from coarse to fine, to expose more fresh surfaces for more complete hydration.
- By using the fine fraction of the recycled material and reclaimed water, nucleation sites for cement crystals are created that are already hydrated and that therefore support additional crystallization.
- Recycled aggregates have some cementitious materials so they encourage crystal growth toward recycled aggregate, providing a better microstructure.
- With the cementitious material available within the recycled aggregate and water, a reduced total cementitious content was possible.
- Using recycled aggregate made it possible to use more SCM as a replacement for cement, producing more dense concrete.
- The blend of SCM and cement created additional lime to react with slag, resulting in an increase in strength gain and paste density.
- Attributes of the new mix include:
 - Only a 70° F temperature rise, eliminating the need for cooling mass concrete placements.
 - The retardation effect on early-age strength gain can be controlled and 3000-psi compressive strength at three days is common.
 - It is essentially self-consolidating even though the w/c ratio is 0.34. With improved fluidity, the mix is easier to place, and needs minimum vibratory equipment and fewer personnel.
 - The new mix exceeds traditional mixes in reduced shrinkage, higher dimensional stability, and improved paste density and salt resistance.
 - It has improved resistance to alkali-aggregate reactivity.

The transport cost for aggregate continues to increase, doubling every 12 additional miles from the source. And finding good sources of virgin material close to major metropolitan areas, and getting them permitted, is increasingly difficult. Recycled aggregate, on the other hand, is closer to the point of use, eliminating high transportation costs. As a bonus, this new-generation concrete is stronger, has a longer life cycle, and saves money in replacement costs.

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