

When did you last review your concrete specifications?

Writing concrete mix specifications to improve durability and sustainability

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Problem and Solution

Concrete mixes primarily rely on portland cement (ASTM C150) to provide the concrete's desired performance, which is why traditional concrete mix design specifications emphasize cement usage as a pseudo-metric for strength and durability. These specifications often included minimum portland cement content requirements as a "proof of purchase" for the concrete.

But increased fundamental knowledge from research and growing empirical evidence now show that unintended consequences from this approach make it antiquated. Specifically, it is now known that strict emphasis on minimum cement contents can increase environmental impacts and worsen performance—yet potentially still cost more than modern advanced concrete mixes. Portland cement manufacture produces most of the environmental impacts associated with concrete because it is made by superheating raw geological ingredients to force a chemical reformation. This costly yet necessary process produces carbon dioxide as a primary byproduct. Modern

concrete mix designs, on the other hand, can reduce this environmental impact while maintaining performance requirements by minimizing the quantity of portland cement. These designs do this by replacing some of the cement with supplementary cementitious materials (SCM) such as fly ash, natural pozzolans (both under ASTM C618), silica fume, and slag cement (ASTM C989).



Modern mixes also minimize the required amount of cement paste (cement combined with SCMs and water) in the concrete by optimizing aggregate gradations. Besides reducing the cement content needed for a concrete mixture, SCMs and optimized aggregate gradations also increase

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concrete's performance and longevity. Together, or individually, these mix design advancements can decrease the concrete's cost, and both lessen its environmental impact and increase its durability.

Many local governments have not revised their concrete mix specifications in years—leaving in place minimum cement content requirements and other elements that are out of step with modern practices. Reviewing older specifications and replacing obsolete requirements with modern elements is crucial. Fortunately, concrete suppliers in California are familiar with, and already producing, these modern mixes for Caltrans, private customers, and other agencies that have begun implementing these specification updates.

Sustainability Benefits

Making these specification changes provides sustainability benefits:

- *Use dense aggregate gradations.* This minimizes the need to fill the voids between aggregates with cement paste. Cement paste shrinks as it cures, due to water leaving the system, increasing the risk of cracking. Using less cement paste will result in less shrinkage. Since cement is more expensive than aggregate, this change may also reduce cost.
- *Require quality control and quality assurance testing to ensure that the concrete has the strength and performance properties of interest.* There is a small cost for sampling and testing, but those costs are very

small compared to the increase in life cycle cost (including maintenance costs) of poorer quality materials.

- *Require use of supplementary cementitious materials (SCM) such as fly ash, natural pozzolans, or slag cement.* The use of SCMs tends to reduce shrinkage and improve durability, as well as reduce greenhouse gas emissions.
- *Allow the use of blended cements (ASTM C595).* These come from the cement plant with the portland cement and SCMs already blended together.

The plot on the next page compares greenhouse gas emissions from three concrete mixes: one without SCMs recently used on an urban street by a local California government, one without SCMs used by a local government for minor concrete, and one with SCMs recently used on a state highway pavement that meets Caltrans specifications. The mix components are shown in the subsequent table. The trends for energy use and particulate emissions (PM2.5) follow those for greenhouse gases. These examples give an idea of the potential environmental benefits achievable by updating concrete specifications.

Understanding the SCM Cost Factor

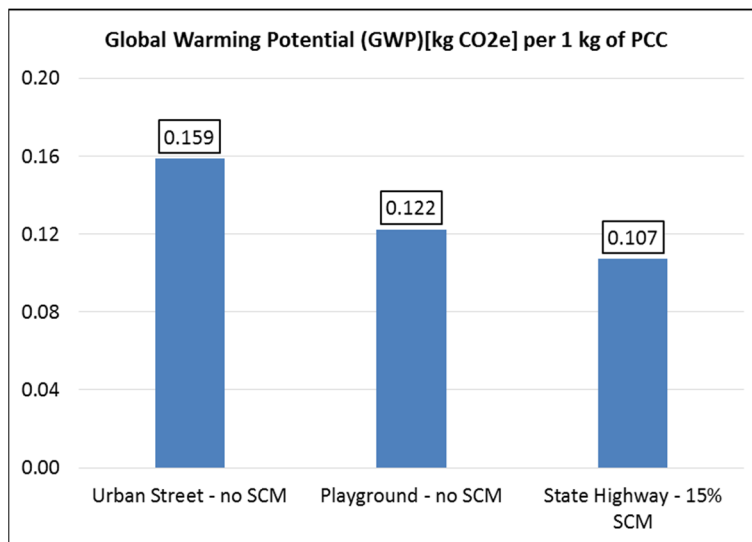
The SCM market in California is constantly evolving and transitioning. The most prevalent SCM materials—such as fly ash, silica fume, and slag cement—are all byproducts of other industries (coal, steel, and iron, respectively). Fluctuations in those

industries carry over to the SCM market. Other SCMs, such as natural pozzolans, have entered the market to help fill growing national demand, and several others are being explored. In general, these SCMs are less expensive than portland cement. Therefore, whenever possible, give the concrete supplier flexibility to select the specific SCM for a given project, and base your acceptance of the concrete on the specified properties measured as part of quality control and assurance. This flexibility will allow the supplier to select the most cost-efficient SCM based on current market

availability, helping to protect you against market volatility.

What You Need to Do

Work with a concrete mix design expert to review your specifications and change them. You can use a simplified version of the elements in the Caltrans pavement concrete mix design requirements. A sample specification will soon be available on the CCPIC website: www.ucprc.ucdavis.edu/ccpic/



Mix Type	Portland Cement (lb)	Fly Ash (lb)	Total Cementitious Materials (lb)	Coarse Agg. (lb)	Fine Agg. (lb)	Water (gal)	Accelerator (fl oz)	Air Entrainer (fl oz)	Water Reducer (fl oz)	w/c Ratio
Local government street mix	705	0	705	1,503	1,464	37	98	0	80	0.44
Local government playground mix	564	0	564	1,903	1,368	33	0	0	23	0.49
Caltrans state highway mix	479	85	564	1,800	1,385	30	0	3	28	0.44

But What About...?

How do I know that these mixes will give me good performance? *These types of mixes have been tried and tested internationally—including in California by Caltrans—for many years.*

Will these changes in specifications cost me more? *These specifications may reduce initial costs, depending on the relative costs of cement and SCMs at any given time, and are expected to reduce life cycle costs based on better durability.*

Are there any other issues such as constructability with these mixes? *Generally, no. Your concrete suppliers can also provide additives, if needed, to help ensure workability and other constructability properties with little impacts on performance.*

How Others Have Done This

Some cities and counties have reviewed and changed their specifications, including the cities of Davis, Berkeley, and Los Gatos—as well as the University of California, Davis campus. Caltrans has used flexural strength requirements and performance requirements (like shrinkage) for many years, and without minimum cement contents. Local government can use compressive strength as a surrogate for flexural strength. Caltrans has been requiring SCMs as a means to achieve these numerous benefits in their concrete for more than 15 years!

Where to Get More Information

Caltrans specifications (Section 90) are already available on the web:
www.dot.ca.gov/hq/esc/oe/construction_contract_standards/std_specs/2015_StdSpecs/2015_StdSpecs.pdf

A simpler example specification will soon be available on the CCPIC website:
www.ucprc.ucdavis.edu/ccpic/