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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 for all applications chiefly rely on portland cement (ASTM C150) to give them strength and durability. For this reason, specifications in traditional concrete mix designs were written to ensure that they used enough cement to meet strength and durability requirements, and often included minimum cement content requirements to be sure the buyer got their money's worth.

Unfortunately, research and practice have shown that this approach can worsen performance and carry the greatest environmental impacts—while still costing more money. The reasons: in addition to being the most expensive component, portland cement produces most of the environmental impacts associated with concrete because it is made by superheating rocks to drive carbon dioxide out of them and into the atmosphere. Modern concrete mix designs can provide a fix because they minimize the need for portland cement by replacing it with *supplementary cementitious materials* (SCM) such as fly ash, natural pozzolans (both under ASTM C618), and slag cement (ASTM C989), and may also minimize the amount of cement paste (cement combined with SCMs and water) required in the mix through the use of dense aggregate gradations. Together or individually these approaches to mix design decrease cost and environmental impact while increasing the durability of the concrete.

Many local governments have not reviewed their concrete mix specifications for many years and so they include minimum cement content requirements and other elements that are out of step with modern practices that Caltrans and many others have been implementing and improving for more than 15 years. A review of older specifications

and replacement of obsolete requirements with modern elements can improve performance, and reduce cost and environmental impacts for all concrete work. Concrete suppliers in California are already producing these types of mixes for state and private customers, so they are already available.

Cost and Sustainability Benefits

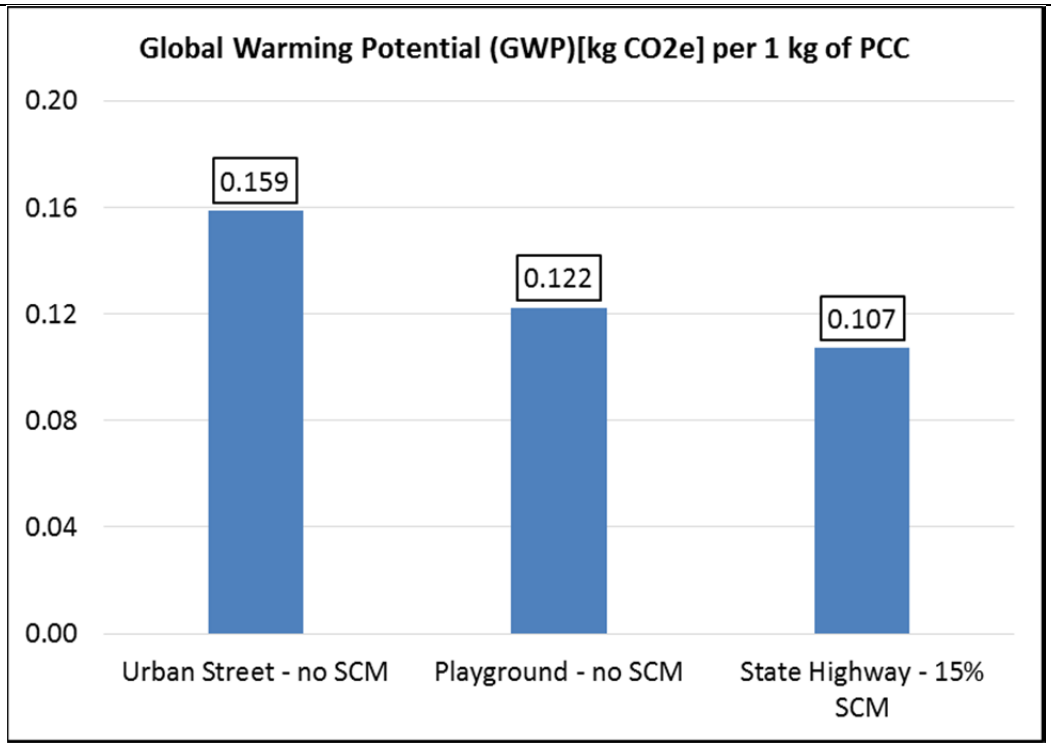
Making these changes in specifications will provide cost and/or sustainability benefits:

- *Use dense aggregate gradations.* This minimizes the need to fill the spaces with cement paste, reduces cost, and reduces shrinkage. Since cement paste shrinks as it cures—increasing the risks of cracking—using less cement paste will result in less shrinkage. And since cement costs more than aggregate, this change should also reduce cost.
- *Specify limits on shrinkage and strength.* Shrinkage limits will dictate the required water-to-cementitious materials ratio, thus reducing water content.
- *Require quality control and quality assurance testing to ensure that you are getting the strength and shrinkage and other 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 of poor quality control.
- *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. Their use may also reduce mix cost.
- *Allow the use of blended cements (ASTM C595).* These already combine portland cement with SCMs.

The plot on the next page compares greenhouse gas emissions from three concrete mixes, two without SCMs recently used by California local governments—one for an urban pavement and one for a playground—and one recently used that meets Caltrans specifications for paving on a state highway. The mix components are shown in the table that follows. The trends for energy use and particulate emissions (PM2.5) follow those for greenhouse gases. These are examples but they give an idea of the potential environmental benefits you can get by updating concrete specifications.

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 also be available soon from CCPIC.



Mix Type	Portland Cement (lb)	Fly Ash (lb)	Total Cementitious Materials (lb)	Coarse Agg. (lb)	Fine Agg. (lb)	Water (gal)	Accel-erator (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? *In general, these specifications will reduce both initial costs and life cycle costs.*

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 at little cost and with no 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—and so has the campus of UC Davis. Caltrans has required flexural strength for pavement concrete (though local government can use compressive strength as a surrogate) and shrinkage specifications for many years, and began requiring fly ash and other SCMs as a means to reduce the risks of cracking due to internal chemical reactions in concrete for more than 15 years.

Where to Get More Information

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

A simpler example specification will be available soon on the CCPIC website.