Low-Carbon Concrete Recommendation to Board of Supervisors

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Contra Costa County Sustainability Commission
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The problem

Concrete accounts for approximately 8% of the world's manmade CO_2 emissions.[1] For comparison, that is more than *three times* the global carbon emissions of the aviation industry (2.5%).[2] But unlike aviation, technologies for mitigating the climate impact of concrete are currently available and economically competitive.

The concrete industry has been able to provide low-carbon concrete mixes for more than a decade.[3] What's more, a cursory Internet search reveals that industry and publicly-funded research is sharply focused on bringing lower-carbon and carbon-neutral products to the market as rapidly as possible.[4]

The opportunity

Any local government strongly committed to reducing embodied carbon in our built environment can start by adopting building codes that require the use of low-carbon concrete mixes.[5] Marin County and several Bay Area cities have already done so.[6]

The concrete industry is already responding to growing demand for less carbon-intensive products. In September 2021, an industry -wide coalition, Concrete Action for Climate, formed with the objective of delivering net-zero concrete to the world by 2050.[7]

Because public agencies buy up to a third of the concrete manufactured annually[8], local governments have the market leverage that can accelerate the research and development of low-carbon concrete.

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[1] "Environmental Impact of Concrete." In *Wikipedi*a. Retrieved January 25, 2022

[2] "Climate Change and Flying; 2020. " In *Our World in Data*. Retrieved January 25, 2022

[3] "Low Carbon with Supplementary Cementitious Materials" Central Concrete.

[4] One example: Martin-Luther-Universität Halle-Wittenberg. "Scientists develop alternative cement with low carbon footprint." Published in *Science Daily,* April 18, 2021.

[5] This recommendation addresses the reduction of embodied carbon (EC) in concrete. A broader approach to reducing EC must tackle concrete use generally. That includes alternate structural methods (e.g. tall timber construction) and engineering that minimizes concrete volume without any loss of strength or durability.

[6] See the County of Marin Low-Carbon Concrete Requirements, Oakland ECAP, Measure B4, Dublin CAP (MM-2 and ML-4), and Berkeley Municipal Code, (Sub-section 19.37.04).

[7] *Concrete Action for Climate*, Mission Possible Partnership. August 2021.

[8] "Concrete needs to lose its colossal carbon footprint," In *Nature*, September 2021.

The obstacle

As we will show, delays in governments' adoption of low-carbon concrete standards cannot be attributed to lack of practical alternatives. Instead, the obstacle appears to be institutional inertia. In June 2019, a University of California research group published a best practices paper which offered its wide-angle perspective: " Many local governments have not revised their concrete specifications in years—leaving in place minimum cement content requirements and other elements that are out of step with modern practices."[9]

Multiple pathways to net-zero

Concrete is a mixture of cement, aggregate, sand, and water. It is the second-most used substance in the world after water.[10] Its global climate impact should compel regulatory agencies, as it already has industry scientists and engineers, to explore every possible approach to reducing concrete's environmental costs.

There are four ways to reduce the embodied carbon[11] of concrete:

1. Reduce and decarbonize the heat energy required in the manufacturing of cement.
2. Reduce the amount of cement in concrete by replacing a portion of it with a less carbon-intensive material that preserves or improves its strength and durability.
3. Substitute limestone aggregate with a synthetic, carbon-sequestering aggregate that uses locally-sourced stone or recycled concrete rubble.
4. Blend captured CO_2 into fresh concrete during mixing, thereby sequestering it from the atmosphere.

The first approach focuses on the manufacturing of concrete, and can be implemented at plants and quarries around the county. The following three approaches address the composition and design of concrete mixes for specific applications, and generally take place at ready-mix facilities. Local building codes can regulate those practices.

Reducing cement in concrete

Cement accounts for only 10-15% of concrete by weight but more than 90% of its CO_2 emissions. Therefore, the most effective approach to reducing concrete's global warming potential is to substitute a portion of cement with less carbon-intensive materials that perform as well or better. They are called substitute cementitious materials, or SCMs.

The most commonly used SCMs, or pozzolans, are fly ash and slag. They are products of fossil fuel industries (coal-fired power plants and steel production, respectively). These materials are

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[9] "When did you last review your concrete specifications?" City and County Pavement Improvement Center, UC Davis and Berkeley. June 2019.

[10] Gagg, Colin R. "Cement and concrete as an engineering material: An historic appraisal and case study analysis". *Engineering Failure Analysis. 40: 114–140*

[11] The major sources of embodied carbon in concrete are the fossil fuel energy expended for the quarrying of limestone, heating the limestone to extremely high temperatures, and the long-distance transportation of cement and aggregate. A second major source of emissions is the CO_2 and heat released during the curing process.

cheap, abundant, and meet engineering requirements for most applications. However, fly ash and slag are not without potential challenges.

In a 2021 paper[12], the Sierra Club stated two concerns about fly ash and slag. First, they may present health risks to workers and nearby residents from air-borne dispersion at or near concrete mixing facilities. Secondly, their use monetizes a product of fossil fuel industries.

Based on conversations with a professor of public health[13] and the sustainability director for a major concrete supplier[14], we believe that these concerns have not been sufficiently documented to warrant a delay in the adoption of low-carbon concrete standards, given the overwhelming health and environmental benefits of rapid greenhouse gas reductions. We must not allow the perfect to be the enemy of the good.

Alternatives SCMs

The supply of fly ash will dwindle as coal-fired power plants are phased out. But other SCMs that are *not* by-products of fossil fuel industries are available. A few examples are volcanic ash, calcined clay (mentioned in the Sierra Club paper); silica fume and rice hull ash (Berkeley Municipal Code, chapter 19.37.04).

Recycled glass may be the most environmentally positive SCM. If its use becomes widespread, the practice will divert thousands of tons of waste glass from landfills—a significant step toward achieving a circular economy in a key industrial sector.[15] Last year a Connecticut plant began manufacturing a concrete-grade pozzolan from post-consumer glass.[16] We are not aware of plans to launch a similar facility on the West Coast.

Owing to the growing importance that investors place on Environmental, Social and Governance (ESG) factors, business and environmental considerations are coming into closer alignment.[17] Concrete companies will choose SCMs with lower carbon footprints as long as their supply is reliable, their performance meets engineering requirements, and their price is competitive.

[12] "Sierra Club Guidance: Cement Manufacturing," June 2021.

[13] Professor Emeritus Thomas McKone of the UC Berkeley School of Public Health stated that the most significant pollutant from grinding and handling fly ash is PM2.5. But, he said, other SCMs, such as volcanic ash or limestone, pose similar risks so proper handling practices must be followed in any case.

Embedded in concrete, fly ash and slag are not "bio-available." Professor McKone said their use as SCMs is, therefore, a safer "disposal" method than heaping the material on the ground, where their toxic components can contaminate soil and leach into groundwater. Phone conversation.

[14] "No fossil fuel plant could operate solely on the sale of fly ash." Juan Gonzalez, Sustainability Director, Central Concrete..

[15] "The Circular Economy and the Promise of Glass in Concrete," Google and the Ellen MacArthur Foundation, 2016.

[16] "Ground Glass Positively Premiers." *Concrete Products*, May 2021.

[17] Phone interview with Juan Gonzalez, Sustainability Director, Central Concrete.

Synthetic aggregates and CarbonCure technologies

Two promising technologies sequester CO_2 obtained from current industrial operations. Blue Planet's synthetic carbon-sequestering aggregate replaces limestone gravel, transported by rail thousands of miles from quarry sites. The company has applied for a permit to open a plant in Pittsburg. The Blue Planet technology combines captured CO_2 with calcium sourced from waste. Its website states "[Its] aggregate is so carbon negative that it offsets all the emissions from the cement in the concrete, making the mix carbon negative."[18]

CarbonCure is another proprietary technology for sequestering carbon. The method involves injection of captured CO_2 into fresh concrete during mixing. This technique can also be used in production of precast concrete and concrete block. According its website, CarbonCure improves concrete's compressive strength and significantly reduces its carbon footprint.[19]

A number of other technologies for reducing the global warming potential of concrete are emerging, but these two are locally available and ready for use.[20]

Approach to regulation

These methods are not stand-alone mitigations. Used together, they can produce concrete that is carbon-negative.[21] In other words, they can offset more carbon through carbon capture, sequestration, or avoidance, than they emit.

Given the ongoing, rapid development of new technologies, the most practical approach to regulating embodied carbon must be flexible: establish standards that limit total embodied carbon, or global warming potential, of a project. Project applicants will then choose the most appropriate way to meet to meet those standards, based on technical requirements, design considerations, cost, and availability.

The low-carbon concrete requirements developed by the County of Marin [22] as "model code" under a BAAQMD grant, take this approach. In partnership with stakeholders across the region, the County established codes that provide for two alternative compliance pathways:[23]

1. Limit the maximum allowable amount of cement (specified in lbs/yd^3) necessary to achieve the compressive strength required for specific applications; *or,*
2. Limit the maximum embodied carbon ($kg\ CO_2e/m^3$) of the total concrete usage within a project. This value is calculated using the Environmental Product Declarations (EPDs) for particular concrete mix designs.

[18] Blue Planet website. Retrieved January 26, 2022.

[19] Carbon Cure website. Retrieved February 9, 2022

[20] See the Sustainability page of the Central Concrete website.

[21] Mr. Juan Gonzalez. See earlier citation.

[22] County of Marin, Low Carbon Concrete Requirements.

[23] Marin County Code Chapter 19.07, table 19.07.050

Compliance under the first pathway is achieved, in essence, by following a recipe. Because it is simple, most contractors follow this pathway.

The second pathway, though more complex, leaves the door open for meeting the standards through any combination of SCMs, synthetic aggregate, CO_2 injection, or even cement substitutes that may be on the horizon. It seems that the Marin low-carbon requirement is future-proofed.

Our recommendation

Consider the landscape before us. We see:

- A growing number of jurisdictions adopting low-carbon concrete standards;
- An industry that already offers lower-carbon products and is incentivized to deliver still lower-carbon materials and technologies;
- Practical and flexible low-carbon concrete building codes currently in effect;
- And especially, a *rise of more than 6%* in global greenhouse gas emissions in 2021, compared to the previous year.[24]

Against that background, we urge the Sustainability Commission to recommend that the Board of Supervisors direct staff to study adoption of low-carbon concrete standards.

We further recommend that these standards be implemented through reach codes that would apply to all new construction in unincorporated Contra Costa.

[24] The spike was largely a rebound from the pandemic-induced drop in energy use of 2020. "U.S. Greenhouse Gas Emissions Bounced Back Sharply in 2021," New York Times, January 10, 2022.