Climate Action:

WHAT YOU CAN DO RIGHT NOW

BUILD WITH STRENGTH

960 W. 7th Street, Los Angeles.
The design and construction team implemented several Top 10 strategies to reduce the embodied carbon of concrete for this new residential tower in Los Angeles. Photo courtesy of Brookfield Properties.

THE TOP 10 WAYS TO REDUCE CONCRETE'S CARBON FOOTPRINT

The following is a list of strategies for reducing concrete's carbon footprint through collaboration, design optimization, and performance-based specification:

- Communicate carbon reduction goals
- Specify supplementary cementitious materials
- Don't limit ingredients
- Ensure good quality control and assurance
- Specify admixtures
- Sequester carbon dioxide in concrete
- Optimize concrete design
- Set targets for carbon footprint
- Encourage innovation
- Specify innovative cements

WHY IS THIS IMPORTANT?

According to the U.N. Environment Global Status Report 2017, the world is projected to add 2.5 trillion square feet (230 billion square meters) of buildings by 2060, driven by soaring needs for housing and infrastructure development. The UN report urges building designers and owners to reduce operational carbon by designing disaster-resilient buildings for the future with zero-energy consumption. Concrete has long been the material of choice for energy efficient and disaster resilient buildings and infrastructure. The UN report also urges the building industry to reduce the embodied carbon of building materials. Given the amount of concrete used in buildings, and the carbon footprint of making cement, the challenge is to offer lifetime benefits of concrete at a lower carbon footprint.

To meet this challenge, the National Ready Mixed Concrete Association (NRMCA) adopted in 2012 the Architecture 2030 Challenge, which has goals to reduce operational carbon and embodied carbon from the built environment to net zero by 2050. However, concrete is unique among building materials. Design professionals and contractors have a greater influence on concrete formulation than they do with other building products. Therefore, it is critical that architects, engineers, contractors and concrete producers collaborate to reduce concrete's carbon footprint. And, given that structural engineers often specify concrete on projects, architects need to know more about how to talk with their consultants to reduce the embodied carbon in concrete.

WHAT YOU CAN DO RIGHT NOW

1. Communicate carbon reduction goals

Sustainability goals, including carbon footprint targets, should be communicated to the design team and to product manufacturers. This not only applies to concrete but to the majority of building products specified. We suggest collaborating with your structural engineer, local concrete producers, and contractors. Invite them in for a meeting or charrette with your design team. Understand what technologies and concrete ingredients are available locally. Emphasize the carbon reduction goals for the project in pre-bid meetings. Carbon reduction of 50% and higher is readily achievable.

Recommendation: State a carbon reduction goal (carbon budget) for all the concrete on the project. See Section 1.2 of NRMCA Guide Specification.

2. Ensure good quality control and assurance

Concrete is made from local materials and its performance can be affected by weather conditions, variability of materials, delivery, placing, handling, and testing. Although the materials used to make concrete meet rigorous standards, the variability can be quite high. Concrete rarely tests well when proper manufacturing, installation, and testing protocols are not followed. If test results consistently show lower strength, then the only way to overcome that is to increase overdesign, which generally raises cementitious material content. For example, if poor testing increases the necessary over design from 600 to 1000 psi, the content of the cementitious materials would increase by roughly 40 lbs to 4,000 psi, increasing the embodied carbon footprint by as much as 6%.

Recommendation: Specify minimum qualifications for the concrete producer, installer, and testing facility. See Section 1.7 of NRMCA Guide Specification.

3. Optimize concrete design

If a structural element such as a column or beam is designed larger than required, then excessive concrete is being used, which increases embodied carbon. Alternatively, for a high-rise building, reducing the size of the columns might be critical to keeping the rentable space to a maximum. That means using high-strength concrete, which generally means higher carbon footprint, but at lower volume with a net benefit to the project. Additionally, higher quality materials can allow for innovative design strategies such as increased deck spans with less deflection, or narrower columns to withstand equivalent seismic and wind drift.

Recommendation: Discuss sizing of structural members with your engineering consultants. Use life-cycle analysis software to quickly calculate the embodied carbon of concrete elements throughout design iterations (structural and architectural). Also, consider exposing concrete wherever possible. Finished materials have a considerable carbon footprint whereas exposed concrete provides an attractive alternative option. Exposed concrete has a higher rate of carbon uptake through a process called carbonation, which permanently sequesters CO_2 directly from the atmosphere (see Strategy 9). Additionally, exposed concrete is fire resistant without the need for additional protection, unlike other materials.

4. Specify innovative cements

There are several innovative cements on the market. The most common are called blended cements. These combine ordinary portland cement (OPC) with other materials. The most common type of blended cement is portland-limestone cement (PLC) or, technically, ASTM C595 Type IL cement. This blended cement combines up to 15% limestone interground with OPC to make a cement with a carbon footprint that is up to 10% lower than OPC with performance that is identical to—and in some cases better than—OPC. As a 1-to-1 replacement, incorporating PLC into a project allows for direct reduction in carbon across all classes of concrete. There is also another standard, ASTM C1157, for performance-based blended cements with no limits on cement composition, which allows considerably more flexibility.

Recommendation: Coordinate with your structural engineer to permit the use of all hydraulic cements including ASTM C150, ASTM C595, or ASTM C1157. See Section 2.2 of NRMCA Guide Specification.

5. Specify supplementary cementitious materials

Nearly all concrete uses supplementary cementitious materials (SCMs). SCMs offer the greatest opportunity for the reduction of carbon footprint today. The most common are fly ash, slag cement, and silica fume in that order. However, there are others, such as metakaolin, volcanic ash, rice husk ash, and ground glass, to name just a few. All these, when combined with portland cement, also enhance the performance of concrete with increased strength, durability, and enhanced workability. Given that they are often recycled or naturally-occurring products, SCMs are a carbon-reduction strategy that frequently yield negligible impact to cost.

To give an idea of how effective the use of SCMs are in reducing carbon footprint, going from a 100% portland cement mix to a 50% fly ash/slag cement mix can reduce carbon footprint by roughly 40%. Additionally, present-day projects can easily realize more than 70% cement replacement with SCMs for foundations that won't experience ultimate loading until the project nears completion.

With SCMs other than silica fume, the rate of strength gain might be lower initially, but strength gain continues for a longer period compared to mixtures with only portland cement or blended cement, frequently resulting in higher ultimate strengths. This slower strength gain can sometimes be overcome with admixtures. However, the most common way to overcome slower strength gain is to specify a later test age. For example, foundations are often specified to reach compressive strength tested at 56 or 90 days to allow for slower strength gain.

Recommendation: Permit all types of SCMs in your specification. See Section 2.2 of NRMCA Guide Specification. Coordinate with the engineer and contractor to maximize the use of SCMs while balancing schedule demands, including using compressive test age of 56 or 90 days depending on the application.

6. Specify admixtures

Nearly all concrete produced today uses admixtures. Most enhance the plastic properties in order to make concrete more workable, economical, shorten or lengthen set time, and so on. There are water-reducing admixtures that in effect reduce cement demand, accelerators that improve strength gain, and viscosity modifiers that permit concrete to flow into very tight spaces. As an example of how effective admixtures can be, using a water-reducing admixture that reduces water content in a mixture by 12% will result in a reduction of cement content by 70 lbs for equivalent slump and strength, with a carbon reduction of roughly 10% for 4,000 psi. High-range water-reducing admixtures can reduce water content by as much as 40%.

Recommendation: Permit all types of admixtures in your specification.
See Section 2.2 of NRMCA's Guide Specification.

7. Set targets for carbon footprint

The best approach to achieve carbon footprint reductions is to use a whole-building life-cycle assessment to set a carbon budget for all the concrete in a building. Use industry-average benchmarks to establish a baseline and use industry-wide environmental product declarations to establish a carbon budget (see recommendations). It is still necessary to have a general idea of what the carbon footprint of each mix will be to set a carbon budget for the building. By setting a carbon budget for all the concrete, it provides enough flexibility to the contractor and concrete producer to meet the all the performance criteria, such as strength and durability, while also meeting carbon reduction goals.

For some elements, such as post-tensioned slabs, the ability to reduce carbon footprint from industry-average benchmarks will be difficult because of early strength requirements. But for other elements, such as foundations and shear walls, the carbon footprint can be significantly lower than benchmark. The carbon budget approach allows for the contractor and concrete producer to combine many of the strategies presented, such as implementing good quality control and using innovative cements. SCMs and admixtures to help meet the performance requirements and carbon reduction goals.

Recommendation: Specify a target Global Warming Potential (GWP) for all the concrete on the project by using NRMCA Industry Wide Environmental Product Declarations and Benchmarks to compare your proposed designs to a baseline (benchmarks). See Section 2.11 of NRMCA's Guide Specification.

8. Don’t limit ingredients

Do not list a maximum or minimum cement content, maximum or minimum SCM content, or quantity of admixtures. These random limits on material ingredients in project specifications limit the concrete producer’s ability to meet performance criteria, including carbon footprint reductions. As an example, unnecessarily limiting the water-cementitious ratio to 0.45, versus an alternative of 0.50, can result in an increase in GWP of 7-12%. Instead, use ACI 318’s exposure classification table when conditions would require limits on the water-cementitious ratio.

Recommendation: Include a table in the specification that lists performance criteria, such as strength and exposure class, without limitations on material quantities. See Section 2.11 of NRMCA Guide Specification.

9. Sequester carbon dioxide in concrete

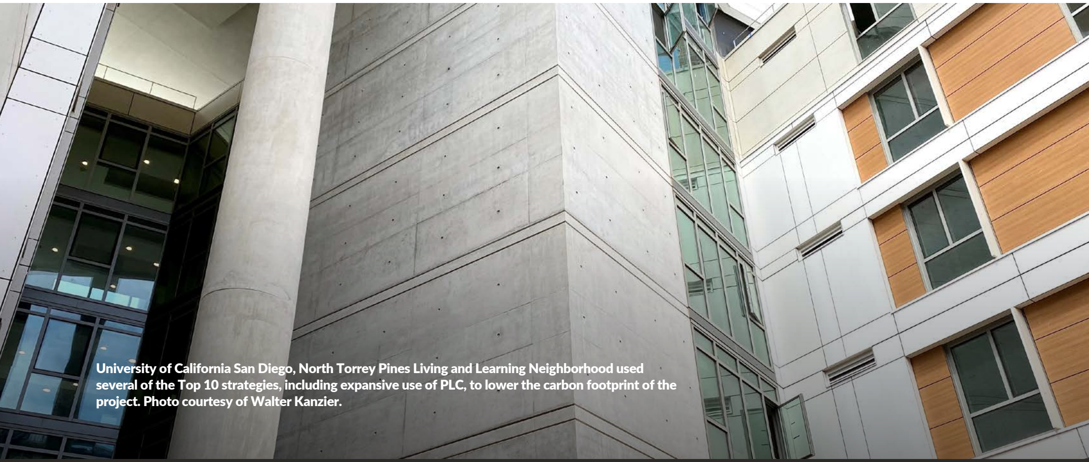
Carbon dioxide (CO_2) can be captured or permanently sequestered in concrete through natural processes or carbon mineralization technologies. The rate of carbon uptake depends on exposure to air, surface orientation, surface-to-volume ratio, binder constituents, surface treatment, porosity, strength, humidity, temperature, and ambient CO_2 concentration. Research conducted by Possan, indicates that during its lifetime, concrete can uptake anywhere from 40% to 90% of CO_2 emitted in its manufacturing process. Other commercially-viable technologies accelerate carbonation. This is accomplished either by injecting CO_2 into concrete, curing concrete in CO_2, or creating artificial limestone aggregates using CO_2.

Recommendation: Expose concrete as much as possible on projects. Permit the use of recycled and artificial aggregates in concrete. Permit the use of carbon mineralization technologies. See Section 2.2 of NRMCA Guide Specification.

10. Encourage innovation

For an innovative product or process to be successful, demand must be created, but the current design-bid-build process discourages innovation.

Recommendation: Communicating the carbon reduction goals to contractors and producers during the design process is critical. Let them know that you are looking for innovative solutions. Most sophisticated producers are experimenting on new formulations all the time. Ask them to discuss some of their low-carbon concretes. Will they meet all the performance criteria set by the design team and the contracting team?



University of California San Diego, North Torrey Pines Living and Learning Neighborhood used several of the Top 10 strategies, including expansive use of PLC, to lower the carbon footprint of the project. Photo courtesy of Walter Kanzier.

TOOLS AND RESOURCES

Guide to Improving Specifications for Ready Mixed Concrete with Notes on Reducing Embodied Carbon Footprint, NRMCA Publication 2PE004-21c, 2021. **www.nrmca.org/sustainability**

NRMCA Member Industry-Average EPD for Ready Mixed Concrete NRMCA 2021.
https://www.nrmca.org/wp-content/uploads/2022/03/NRMCA_EPDV3-2_20220301.pdf

A Cradle-to-Gate Life Cycle Assessment of Ready-Mixed Concrete Manufactured by NRMCA Members — Version 3.2. NRMCA 2021.
https://www.nrmca.org/wp-content/uploads/2022/02/NRMCA_LCAReportV3-2_20220224.pdf.

E. Possan, E. F. Felix, W. A. Thomaz, *CO_2 uptake by carbonation of concrete during life cycle of building structures*, Springer International Publishing, Switzerland, October 2016.

Engage the Concrete Design Center for help with sustainable concrete design and specifications, **www.buildwithstrength.com/design-center**.

Learn about the latest concrete innovations at **www.concreteinnovations.com**.

BUILD WITH STRENGTH