Solving Embodied Carbon Challenges With Concrete Specifications

How a small shift to performance-based specifications can remove barriers to innovation and sustainability in concrete.

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Introduction

The world's building stock is expected to double by 2060 — that's equivalent to adding an entire New York City to the planet every month for the next 40 years.

Nearly 50% of total carbon emissions from this new construction is expected to come from embodied carbon, which is the carbon footprint of a building before it becomes operational. The increased demand for the manufacturing of building materials such as concrete, wood and steel represents a challenge for meeting global carbon emission reduction targets.

To address the challenge of embodied carbon, a number of organizations including Architecture 2030, Structural Engineers 2050 Challenge (SE2050), the Carbon Leadership Forum, and the World Green Building Council have jointly taken on a mission to eliminate it from buildings by the year 2050.

Thankfully, concrete also represents a solution to the global carbon challenge. New innovations are available today that can reduce the amount of carbon dioxide (CO_2) emitted in the concrete production process — and even remove some CO_2 from the atmosphere, storing it permanently in the concrete itself.

These innovations in concrete can make a real difference — but only if specifiers transition from traditional prescriptive specifications to modern performance-based specifications.

This eBook explores how specifiers can remove barriers to sustainability in concrete and provides actionable tips on making the switch from prescriptive to performance specifications today.

One of the simplest ways to move the needle on embodied carbon is to change the way concrete is specified.

Understanding Prescriptive and Performance Specifications

Traditionally, the construction community relied on prescriptive specifications for concrete mix designs. Many commercial projects—and nearly all public building and infrastructure projects—still use prescriptive specs today.

These prescriptive specs outline criteria for **how concrete is made**. They include clauses for the methods of construction and impose restrictions on the compositional parameters of concrete mix. For example, prescriptive specifications may prescribe a minimum cement content of 700 lb/yd^3 (415 kg/m^3) or a maximum fly ash content of 25%. In some cases, prescriptive specifications may entirely disallow certain ingredients.

Performance-based specs, on the other hand, outline criteria for **how concrete needs to perform**.

Performance specifications make more sense in the modern construction landscape as they do not put parameters around the components or proportions of the mixture. Instead, performance specifications are based on performance indicators like strength, permeability, shrinkage, sulfate resistance, resistance to alkali-silica reaction, etc.

These indicators are measured by standard test methods with defined acceptance criteria e.g., chloride permeability no greater than 1,500 Coulombs at 56 days.

Performance specifications empower the concrete producers — the experts in concrete mix design — to propose the best concrete mix to meet the performance needs of the required application.

Studies have shown that performance-based concrete specs are more likely to result in better-performing concrete, with better sustainability profiles—and often with lower costs—than prescriptive specs. They also represent one of the most significant embodied carbon reduction strategies available that can be implemented today.

The Cost of Prescriptive Specifications

Prescriptive concrete specifications are often overly conservative, which can not only lead to higher costs and but a less sustainable product.

Variations of historical prescriptive specifications persist in the construction industry as they are copied and amended for new projects, mostly from habit.

Below is an example of a prescriptive specification from Canada. It was originally published in 1942, yet variants of it are still widely used today. One of the clauses states that admixtures are not recommended. In 1942, admixtures were new and there was a general mistrust of them in the industry.

> ADMIXTURES
>
> 28. Admixtures are not recommended. If used in concrete it shall be only with the approval of the Engineer, based upon evidence that the compressive strength of the concrete will not, with the passage of time, be reduced more than 10 per cent or other impairment of desirable qualities brought about by the use of such admixtures.

Imagine if this specification still existed in this form today? It would mean that the use of water reducers, superplasticizers, etc. would be limited.

While this particular specification has evolved to prescribe the use of admixtures, it demonstrates how restrictions can impede innovation in other areas of concrete mix production — the same way that admixture innovation was impeded in 1942.

Examples of prescriptive requirements included in these specifications from 1942:

- Limitations on source and composition of materials
- Minimum cement factors
- Limitations on supplementary cementitious materials (e.g. quantity, type, composition)
- Water to cement ratio limits (when durability doesn't apply)
- Aggregate grading requirements
- Requirement to use potable water
- Limitations on the composition of mixtures
- Restrictive requirements for slump or air content
- Restrictions on concrete temperature outside standards

Overly Prescriptive Specifications

The National Ready Mix Concrete Association (NRMCA) surveyed 102 project specifications to identify the true extent of prescriptive limitations. They found the most common prescriptive requirement to be a restriction on the amount of supplementary cementitious material (SCM) that can be used in concrete — 85% of specifications contain this restriction.

While limitations in SCM make sense in certain exposures (e.g., where concrete is exposed to de-icing salts, freezing, and thawing), in other exposures the restriction is redundant and may even lead to lower quality concrete. Despite this, specifiers often copy existing prescriptive specifications and, therefore, unnecessarily restrict the use of SCMs.

The NRMCA also found prescriptive water to cement ratios were applied in 73% of specifications where the limitations were not even applicable.

Prescription	% of specs	Where Applicable?
Restriction on SCM quantity	85%	ACI 318 - for F3 only
Max w/cm (when not applicable)	73%	ACI 381 - for durability only
Minimum cementitious content	46%	ACI 301 - for floors
Restriction on SCM type, characteristics	27%	None
Restriction on aggregate grading	25%	Suggested for floors

These prescriptive specifications result in overly concrete mixes that are not optimized for the performance requirements of the specific use case.

More Efficient, Low-Carbon Concrete with Performance-Based Specifications

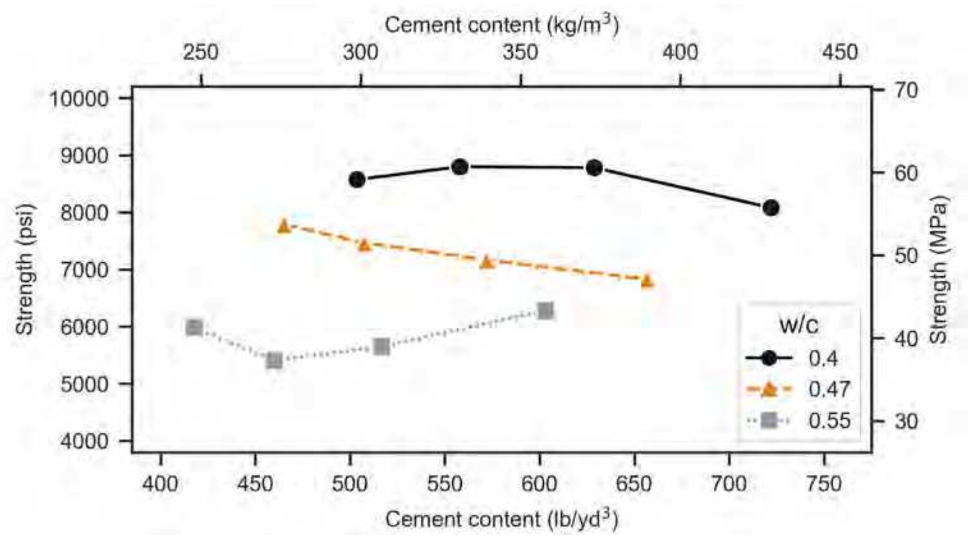
Prescriptive specifications are outdated and prescribed for scenarios that are no longer relevant today. Specifiers can minimize prescriptive-based specifications and drive innovation in concrete mix design in the following ways:

1. Avoid Specifying Minimum Cement Quantities

There is a perception that more cement makes better concrete. However, research over the past 100 years has shown that it is not the cement content that controls the strength or permeability of concrete, it's water to cementing materials ratio.

In some cases, more cement can actually reduce concrete performance. Studies have shown that going from 500 lb/yd^3 to 700 lb/yd^3 (296 kg/m^3 to 415 kg/m^3) of cement results in no increase in strength. Instead, it results in an increase in heat and cracking, an increased risk of alkali-silica reaction (ASR), and an increase in the embodied CO_2 of the concrete.

40% Slag Mixture



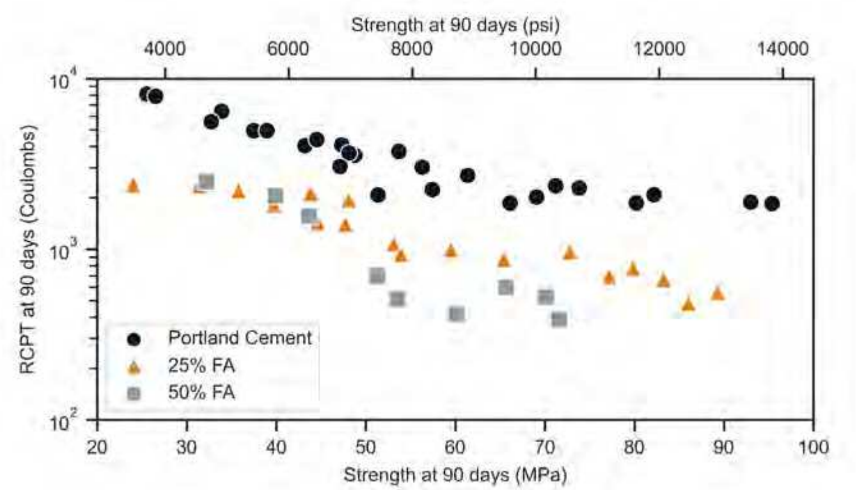
Source: Webinar with Dr. Thomas

Minimum cement contents are no longer an effective way to ensure durability. As such, they have disappeared from many – but not all – national specs.

2. Replace Water to Cement Ratio Criteria

Higher strengths do not equal better durability. Today there are so many different types of cementing materials and producers can discover very different relationships between strength and permeability or other durability factors.

With Portland cement, as strength increases, permeability decreases. However, concrete with 50% fly ash, at the same strength as Portland cement, is almost 10 times less permeable. As such, water to cement ratio starts to lose meaning as we change the nature and type of cement. Despite this, maximum water to cement ratio values are still imposed in most specifications.



Source: Webinar with Dr. Thomas

Consider ASTM C1202 (a standard test method for resistance to chloride ion penetration) to replace the water to cement ratio by using an alternative criteria where the maximum charge passed is specified:

w/cm = 0.50 → 2500 coulombs
w/cm = 0.45 → 2000 coulombs
w/cm = 0.40 → 1500 coulombs

3. Avoid Limits on SCM Quantity

Other than on assigned exposure classes, don't limit SCM quantity as it increases the risk of ASR, delayed ettringite formation (DEF), sulfate resistance, chloride resistance, and reduces later-age strength and durability. Restrictions on SCMs also limit the reduction in cement content, contributing to greater embodied CO_2 in the concrete.

4. Consider Low-Carbon Alternatives

To tackle the embodied carbon dilemma, producers can adopt technologies like CarbonCure. CarbonCure injects CO_2 into the concrete during mixing, similarly to an admixture. Once introduced to the concrete mix, the CO_2 chemically converts to a mineral and is permanently trapped in the concrete. This process actually improves the concrete's strength, which allows greater opportunity for mix optimization.

Eliminating Barriers to Innovation: A Call to Action for Specifiers

Structural engineers, building owners, and public agencies who haven't already transitioned to performance-based spec practices, **the time to act is now.**

Here's how you can help:

1. Communicate your commitment

Ensure your supply chain partners are aware of your commitment to reducing embodied carbon. Sustainability often falls through the cracks of the complex construction supply chain simply due to poor communication.

Make a public commitment on your website and empower your construction partners to bring low-carbon solutions to you.

2. Eliminate unnecessary prescriptive specifications

In some concrete applications, there are legitimate reasons to consider a maximum water to cement ratio or a maximum supplementary cementitious content. However there are very few circumstances where minimum cement content ever makes sense.

Use performance-based concrete specifications. See the Key Resources section for more information.

3. Ask for EPDs

Ask for Environmental Product Declarations. EPDs are like nutrition labels for building materials that state sustainability impact quantities in a transparent way.

Recognize that EPDs can be a costly initiative for concrete producers. If EPDs are unavailable in your market, explore opportunities to support producers who opt to publish EPDs. For example, if the project owner has a budget to support a commitment to sustainable development, consider leveraging those funds to provide a grant to support the cost of EPD creation. This will not only provide transparency for your project, it will also leave a lasting legacy of transparency in the market!

Subscribe to buildingtransparency.org and use the free open-source EC3 tool to view carbon data assembled from a database of all published EPDs. If you're building in a region with local EPD data, use it to include carbon as part of your procurement criteria.

4. Localize your approach

Recognize that concrete sustainability strategies are not one-size-fits-all. Most materials are sourced regionally which results in significant variability across the country. A concrete mix achieved in San Francisco, California may be completely unrealistic in Lexington, Kentucky due to differences in the locally available materials.

5. Ensure spec language encourages innovation

Consider incorporating the following language into your master concrete specifications:

CO_2 mineralized concrete is permitted (or preferred) where available, pending concrete performance criteria is met.

By including this non-committal, minimal risk language, three major objectives are achieved:

- A commitment to embodied carbon solutions is clearly communicated across your supply chain.
- Concrete producers who believe their market won't allow them to supply concrete made with optimized cement contents will be empowered to adopt those solutions.
- Hesitation by any stakeholder on a construction project to provide materials that don't clearly meet the specification is mitigated.

A Win-Win Solution

CarbonCure reduces the carbon footprint of concrete by introducing recycled CO_2 as an admixture. The technology improves concrete strength so concrete producers can use less cement while maintaining the performance criteria. Concrete created with CarbonCure is supplied to construction sites with minimal, if any, cost differential.

Quite simply, it's the same concrete with less carbon.

While this is a win-win solution that should be ubiquitous across the industry, CarbonCure—and any other sustainable building material innovation—faces barriers created by outdated specification practices in almost every market around the world. This is at odds with emerging policy on climate change, industry missions to reduce carbon, and a host of other modern initiatives driving change in construction.

Specifiers, the time to act is now.

Key Resources

Webinar: The Case for Performance-Based Concrete Specs
Guide: NRMCA's Specifications in Practice
Website: Structural Engineers 2050
Website: Carbon Leadership Forum
Tool: Embodied Carbon in Construction Calculator (EC3)
Resource: Specification Language for CarbonCure Ready Mix Concrete

If you'd like to chat about how you can deliver on performance-based specs with CarbonCure and benefit from more sustainable concrete, please **get in touch** with a CarbonCure representative.

Build for the Future.
Build with CarbonCure.

CarbonCure has been used on thousands of projects ranging from healthcare to higher education, residential developments, and corporate campuses.

For more information about building with CarbonCure concrete, visit **carboncure.com**. To get in touch with a CarbonCure representative, send us an email at **info@carboncure.com** or give us a call at **+1 (902) 448-4100** (Worldwide) or **+1 (844) 407-0032** (North America).