Decarbonizing Concrete

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GSP group

Acknowledgements

Thank you to everyone who participated in our discussions and provided valuable feedback that contributed to the findings in this document. We were able to tap into a wealth of knowledge across sectors and develop a better understanding of how concrete can be decarbonized in the years to come.

Interviewees include:

- Alen Keri, Concrete Ontario (RMCAO)
- Derek Lapierre, Dufferin Concrete
- Brian Wu, Fast+Epp
- Kelly Alvarez Doran & Rashmi Sirkar, Ha/f Climate Design
- Ryan Zizzo & Asvini Keerawella, Mantle Climate
- Doug Hooton (Professor Emeritus), University of Toronto
- Ravi Patel & Bishnu Acharya, University of Saskatchewan

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A practical guide for Landscape Architects looking to reduce the embodied carbon of a project using concrete materials.

Glossary

Class C-2 [Concrete]

is an exposure classification under CSA A23.1 for concrete exposed to chlorides (de-icing agents) in a saturated condition. Most flatwork used by Landscape Architects fall into this category.

Environmental Product Declaration (EPDs)

is a standardized document that report the environmental impact of a product across its lifecycle. The International Organization for Standardization (ISO) has classified environmental product data into Types I, II and III. EPDs are considered Type III data and are the most preferred tier.

Concrete Ontario Member Industry-Wide EPD for Ready-Mixed Concrete is an Environmental Product Declaration referred to in this report and may appear in short form as COMIW EPD for RMC or other variations. All variations are referring to the current document published in 2022.

Global Warming Potential (GWP)

is a measure of greenhouse gas emissions expressed in kilograms of carbon dioxide equivalent (kg CO2e). GWP for concrete is typically reported per cubic meter and serves as the primary metric for comparing different concrete mixtures.

Portland Cement (GU)

is the traditional binding agent in concrete and has been the industry standard for over a century. Limestone and silica are heated to over 1400ºC in a kiln to transform the raw materials into *clinker* that acts as the primary constituent of cement.

Portland Limestone Cement (GUL)

substitutes a percentage (often 5-15%) of clinker with fine limestone. This substitution provides a 10% reduction in embodied carbon, and has become the standard type of cement produced in Ontario.

Ready-Mixed Concrete

is manufactured at a central batching plant and delivered to the construction site in a freshly mixed, unhardened state.

Slag

is a by-product of blast furnaces used in steel manufacturing and a primary SCM in Ontario due to regional availability.

Supplementary Cementitious Materials (SCMs)

are materials that have cement-like properties and are used in concrete mixtures to replace a portion of the cement. Common materials include slag and fly ash.

W/C Ratio

is the water-to-cement ratio in a concrete mix. Lower water ratios produce stronger, more durable concrete but reduce workability. Higher water ratios improve workablility but compromise strength. When aiming to reduce the amount of cement in a conrete mix, *shrinkage limits* can be specified in lieu of W/C ratios to give ready-mixed producers more flexibility to optimize their mixtures for the site conditions and placement temperatures.

Summary

2026

Concrete is among the highest embodied carbon materials used in Landscape Architecture. Most of the embodied carbon in concrete (around 90%) comes from the production of a concrete-binding ingredient, cement. Therefore, carbon reduction at cement plants and reducing overall cement use are two primary strategies for carbon reduction. In Ontario, ready mixed concrete plants have made a transition from Portland Cement (General Use or GU) to Portland Limestone Cement (General Use Limestone or GUL) which provides approximately a 10% reduction in embodied carbon. This reduction informs the new baseline as GUL concrete becomes the norm across Ontario. Beyond this 10% reduction, there are more ways we can make a difference.

What We Can Do

Use less concrete. Until large-scale shifts are made to reduce the embodied carbon in cement production, the most effective way to reduce embodied carbon is by reducing its use. This can be achieved by optimizing concrete thicknesses, shrinking hardscaped areas, relying on alternative hardscape materials, and considering how and when concrete reinforcement is used.

Use **Performance Specifications** by avoiding language that creates strict limitations for the concrete producer to reduce the embodied carbon. Instead, use performance targets that ensure the installed concrete meets your practical and visual needs, without creating limitations along the way.

Understand what **Emerging Technologies and Supplementary Cementitious Materials (SCMs)** are available in your region. Ingredients such as biochar, slag and fly ash can be used to reduce embodied carbon by replacing a portion of cement in the mix. For example, a concrete mix with 20% slag contains 20% less cement if it's a 1:1 replacement. Emerging technologies and SCMs can be an important "lever" for reducing the impact of concrete. Just be cautious with specifying prescriptive ranges (ie. 10-20% slag) because they are not universally applicable. The placement of concrete during warm weather has different requirements than cold weather placement, so the Contractor may need to adjust the mix design to account for this variation. This is where GWP targets come in.

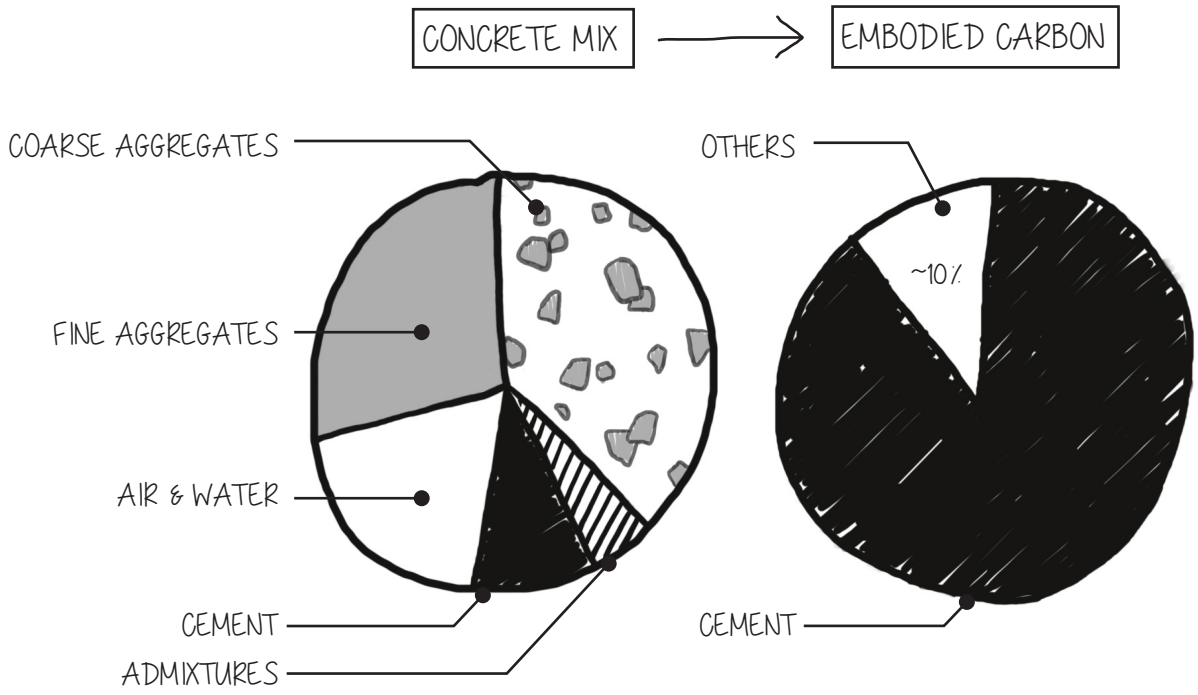


Image 1: Concrete is made up of several ingredients: Course aggregates provide the mass, fine aggregates fill the gaps, air helps with workability and durability, water activates the cement, cement binds everything together, and various admixtures can be used for different applications. Of all these ingredients, cement contributes 90% of the embodied carbon.

Global Warming Potential (GWP) is an industry accepted method of measuring the greenhouse gas emissions in concrete mixtures. One of the simplest ways to decarbonize concrete is by requiring the contractor to supply mix designs that are 10-20% below the industry average GWP. The industry average In Ontario is established by Concrete Ontario within the Industry-Wide EPD for RMC. They compare all available EDPs from ready-mixed plants to establish the mean GWP. This average becomes the baseline that all mixtures should improve upon.

Request Environmental Product Declarations (EPDs) on every project by including them in your Concrete Specifications. EDPs are readily available from Ready-Mixed Concrete producers. Each EPD includes a GWP that allows you to compare apples-to-apples.

Schedule for warm weather concrete placement to allow higher SCM content. When placed in cold weather, concrete mixes contain more cement and admixtures that make it challenging for ready-mix plants to supply mixtures with lower GWP.

Part I
Technical Foundations

Portland Cement

Portland Cement (General Use or GU) has been the foundation of modern construction for over 150 years. Cement production includes the process of *heating* finely ground limestone and clay to extremely high temperatures (1480ºC) to induce a chemical reaction that creates the main component of cement, clinker.

This process is carbon intensive for two reasons:

1. Kilns burn high volumes of fossil fuels that account for ~40% of cement emissions. As cement plants transition to renewable energy and higher efficiency furnaces, the emissions in this category will come down.
2. When limestone is heated to high temperatures to create clinker, it releases high volumes of CO2 as part of the chemical reaction. This process is called limestone calcination, and it accounts for ~60% of cement emissions. Cement plants are looking at innovations including:
    - The incorporation of SCM's
    - Carbon capture technologies
    - Creating cement at lower temperatures

Carbon Capture

The cement industry is pursuing carbon capture technology to reduce the 60% of emissions from limestone calcination. CO2 can be captured off-site and transported to the facility, or it can be captured at the facility. Both options allow CO2 to be added to the water or slag and then mineralized in the concrete prior to placement.

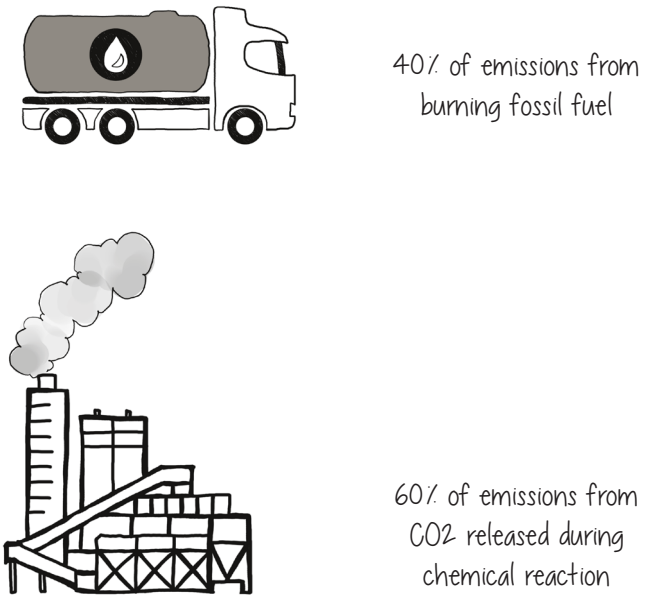


Image 2: Cement Processing Emissions

Portland Limestone Cement

Portland Limestone Cement (General Use Limestone or GUL) is very similar to Portland Cement, however, it replaces a portion of clinker with finely ground limestone that hasn't gone through the furnace. GU and GUL cement are both produced by cement plants and made available to ready-mix plants who prepare the final mixture. Ready-mix plants typically have 1-2 silos for cement at their facilities, making it difficult to carry multiple types of cement. As a result, around 90% of ready-mix plants now carry GUL in place of GU cement. This represents a significant change in Ontario and has resulted in a 7-10% reduction of embodied carbon within the province.

Supplementary Cementitious Materials (SCMs)

SCMs are materials with cement-like properties that can be used to replace some clinker in a cement mixture, or to replace some cement in a concrete mixture. For example, cement plants replace a portion of clinker with limestone when preparing GUL cement. Ready-mix concrete plants replace a portion of cement with slag when preparing concrete mixtures. Limestone and slag are both considered SCMs in these scenarios. SCMs are often industrial by-products, therefore, they vary by region depending on the local industries and availability of associated by-product volume needed by cement and concrete plants. In Alberta, coal-fired power plants produce fly ash as a by-product. Fly ash has historically been a common SCM but is becoming less available with the transition away from coal. In Ontario, steel manufacturing produces slag as a by-product from blast furnaces. This will also change, however, as blast furnaces are upgraded to arc furnaces over time.

As of now, producers cap the amount of SCMs added to a mix as a safeguard for ease of application. For example, Class C-2 concrete mixtures can be blended with up to 25% slag for flatwork applications (expressed as GUL 25SL) with the right ambient temperatures and a qualified installer. Unfortunately, exceeding 25% is not practical for most flatwork applications, but in building foundations it's possible to reach upwards of 70% slag. There are a few reasons for this: building foundations will not experience the same freeze/thaw cycles as Class C-2 concrete, nor does it have exposure to chlorides that will degrade the surface. Understanding these constraints can allow for the substitution of SCMs under the correct conditions. It requires input from the Structural Engineer, placement under ideal temperatures, and proper execution by the Contractor. As specialized application practices for SCM concrete improve across the field, that 25% cap on SCM content could be raised to further reduce the embodied carbon of a concrete mix.

Several promising technologies are being developed as SCMs. Biochar is a charcoal-like material produced from organic waste (often agricultural biomass) that can be used in planting soils, bioplastics, concrete, etc. Researchers at the University of Saskatchewan are experimenting to replace 2.5-3% of cement with biochar and have yielded positive results. Laboratory studies yield a 15% carbon reduction over the concrete's lifetime, and outdoor testing is currently underway. Cellulose nanocrystals (CNC) are another emerging technology that can be added to concrete mixtures. Laboratory studies show a 20-25% increase in compressive strength when using a 0.25% concentration of CNC. These technologies are not quite ready for commercial use in 2026 but may provide solutions that can offset our dependence on cement.

Concrete Exposure Classes

CSA A23.1
CONCRETE MATERIALS

TABLE 1
CLASSES OF EXPOSURE

C-1	Rebar + Chlorides +/- Freeze/Thaw i.e. retaining walls
C-2	Chlorides + Freeze/Thaw i.e. sidewalks, plazas, curbs, stairs
F-1	Freeze/Thaw but no Chlorides i.e. pool decks, tennis courts

Table 1

CSA A23.1 is the Canadian Standard for concrete. Within which, Table 1 breaks down various exposure classes. For Landscape Architects in Ontario, Class C-2 is the most relevant classification. It covers exterior concrete that is exposed to chlorides (de-icing agents) in a saturated condition. This includes most sidewalks, pathways, patios and plazas where the application of winter maintenance salt is expected. The combination of chlorides and freeze-thaw conditions create a harsh environment that degrades concrete.

There are other exposure classes that may apply in certain cases. Class C-1 may apply when the concrete will be exposed to chlorides and reinforcing steel needs to be protected from corrosion. Class F-1 may apply when the concrete will not be exposed to chlorides, but it will be exposed to freeze-thaw cycles.

Environmental Metrics

Global Warming Potential (GWP) has become a standard metric for understanding the embodied carbon of an object or material. It is expressed in kilograms of carbon dioxide equivalent per cubic meter (kg CO_2e/m^3) and, in the case of concrete, it tells us the emissions of a specific concrete mixture. It also allows us to compare one mix design against another, making it a useful tool when seeking reductions.

According to the Concrete Ontario Member Industry-Wide EPD for Ready-Mixed Concrete, prepared in 2022, the average GWP of Class C-2 concrete (32MPa @ 28 days, GU, 10% slag, 0.45 w/cm, with air) is 326.46 kg CO_2e/m^3. With ever changing metrics, it is advised to **specify a percentage reduction from the current baseline**, rather than quoting specific numbers. This helps ensure the spec remains current and applicable, even as industry standards shift.

Concrete Ontario's report was developed from industry averages based on data from 80 participating facilities. The 2022 report will continually be updated, with the next report expected in 2026.

For ready-mixed producers to provide an honest assessment of the GWP, we rely on environmental product data that has been categorized by ISO as Types I, II and III. These data types are either declared by the manufacturer (Type II) or verified by a third-party (Type I and III).

Type II data may provide the desired information but rely on the manufacturer to adhere to best practices when making their claims. A common example of Type II environmental product data is Product Carbon Footprints.

Type I data, commonly referred to as "Eco-labels" are products with preferred

environmental attributes that meet the requirements for credentials—think of the Forest Stewardship Council (FSC) label.

Type III data, or Environmental Product Declarations (EPDs), are the gold standard as they represent the most comprehensive and comparable datasets that inform industry-wide decarbonizing efforts.

A lower GWP is the most widely sought after number on an EPD.

Environmental Product Data

ISO

Classifications (in order of preference)	
Type III ISO 14025	"Environmental Product Declarations (EPDs)" - Third-party verified based on full life cycle assessment of specific product
Type I ISO 14025	"Ecolabels"- Third-party verification of environmental criteria of specific products
Type II ISO 14021	Self-declared environmental claims for industry or product without third-party verification

Table 2

Part II
Design Strategies

Hierarchy of Mitigation

Landscape Architects are uniquely positioned to have a positive impact. No other profession has the opportunity to design with carbon sequestering plants like we do, but offsetting carbon with plantings should be the last strategy when designing spaces.

Alternative concrete reinforcements such as Macro Synthetic Fibres can achieve the same qualities in strength, resist corrosion, and make end of life recycling much easier.

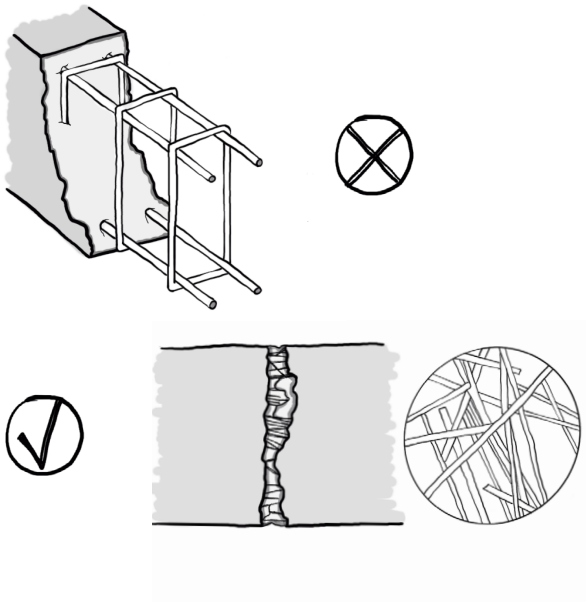


Image 3: Concrete Reinforcement

Use less concrete

It should go without saying, but the most effective way to reduce the embodied carbon of concrete is by using less concrete. We currently have an over dependence on this one material because it is highly versatile, affordable, and durable in our Canadian climate. Consider design solutions such as narrowing path widths, alternative hardscape materials, and alternate wall materials. Not only does this reduce embodied carbon, but challenges us to be more creative and can lead to interesting design solutions.

Reconsider the "norm"— standard details often rely on thicker profiles than required. Adjust concrete and aggregate thicknesses to lower the embodied carbon.

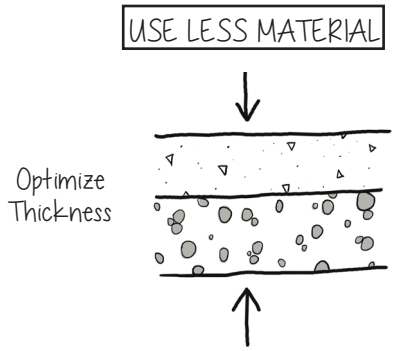


Image 4: Optimize material thickness

Optimize Concrete

When using concrete, consider how thicknesses can be optimized to reduce the overall depth of pavements, widths of walls, and extents of footings. The standard concrete detail for pedestrian applications is 150mm of concrete and 150mm of granular 'A'. Consider modifying these thicknesses more often to suit your application. For example, 125mm of concrete with 150-200mm of granular 'A' might be suitable for pedestrian applications. Decreasing the concrete thickness while increasing the granular thickness will still yield a carbon reduction. Concrete walls are often solid and over-engineered. Consider how the width and mass of the wall can be designed in coordination with Engineers. Similarly, typical footings for walls and site features can be reduced with some encouragement. Consider if it's economical (formwork labour) to hollow out concrete structures, thereby reducing the volume of concrete, cost of materials, weight on the footing, and weight for transport (applicable for precast).

Reduce Waste

While reinforcement is necessary for many applications, there are two primary considerations that should be made:
First, steel reinforcement (welded-wire-mesh and rebar) generally has a high embodied carbon of its own. Second, reinforcement can make it difficult to process concrete for future re-use. Concrete without steel reinforcement is easier to crush and re-use as base material, rip-rap, or aggregate. For more ideas and alternatives like Macro Synthetic Fibre reinforcement seen in Image 3, refer to Meg Calkins's Details and Materials for Resilient Sites: A Climate Positive Approach (2025) and the ASLA's 2024 documents "Decarbonizing Specifications" and "Decarbonizing the Design Process".

Recycled Concrete Aggregate (RCA) can be used in two ways: as a replacement for virgin aggregate in a subbase or in a concrete mix. RCA is well suited as a subbase material as the residual cement can help it harden and stabilize. However, compared to virgin aggregate, the energy required to process RCA for conrete may actually increase the GWP. Additionally, concerns with hydration interference and freeze/thaw durability may limit its current applicability in Ontario.

Part III Specifications

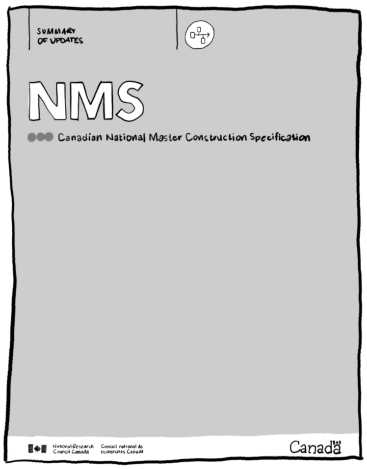


Image 5: NMS Specifications

Start with Current Standards

Purchase the latest version of National Master Specifications (NMS) for up-to-date specification language that includes embodied carbon requirements, EPD submittals, and performance-based approaches. Keeping specifications current ensures you are building on industry best practices rather than outdated templates.

Request EPDs on All Projects

Requiring Environmental Product Declarations creates accountability and builds industry-wide data on concrete carbon performance. Specify that EPDs be submitted for all concrete mixes used on the project. This applies even to smaller projects where you may not be setting aggressive GWP targets.

Approaches to GWP Reduction

There are two ways to structure GWP reduction requirements, each with trade-offs.

Project-wide Reduction

When buildings are part of the project, the consultants can establish a single GWP reduction target for all concrete on the job. This approach is preferred by contractors because it provides flexibility. Foundations can achieve higher reductions (with high slag content), offsetting flatwork where reductions are more challenging. It also accommodates cold weather placement better since the carbon budget can be balanced across the project.

Landscape-specific Reduction

For landscape-only projects or when you want direct control, establish GWP targets within Division 32 specifications. This gives landscape architects clear accountability for their scope but requires good coordination with contractors to avoid cold weather placement that make targets difficult to achieve.

Cold Weather Considerations

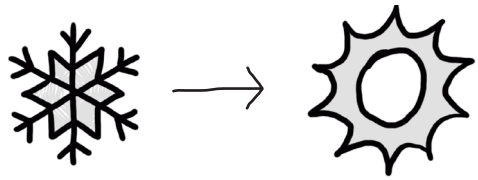


Image 6: Cold vs Warm Weather Placement

Cold weather concrete placement significantly impacts achievable GWP reductions. Slag, the primary SCM in Ontario, performs better in warm conditions. Summer pours could use an estimated 30-35% slag content, while winter pours may be limited to 15%. This seasonal variation means a 30% GWP reduction might be achievable in July but not in January.

When cold weather placement is unavoidable, mitigation options include heating the concrete until it reaches required strength, using accelerating admixtures to speed curing, or providing insulated blankets and enclosures. Each of these adds cost and may affect achievable GWP reductions. Concrete Ontario's guidance suggests allowing a 30% increase to baseline GWP for cold weather, high early strength, and specialty concrete applications.

The best strategy is to build scheduling flexibility into projects. Discuss concrete placement timing at pre-construction meetings and advocate for warm weather placement whenever possible.

Performance vs. Prescriptive Specifications

Performance specifications are strongly preferred over prescriptive specifications for low-carbon concrete. A prescriptive approach (specifying exact mix designs, SCM percentages, or cement types) can inadvertently prevent contractors from using the best available options. What works in one region may not be available in another, and new products enter the market regularly.

A performance approach specifies outcomes: GWP targets, strength requirements, durability performance. The contractor and supplier then have flexibility to meet those outcomes using their knowledge of local materials and capabilities. Frame requirements as "how to achieve lower carbon footprint for the same performance" rather than dictating specific mixes.

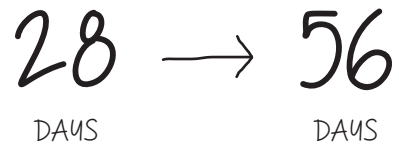
Establishing GWP Targets

To set meaningful GWP targets, you need a baseline for comparison. Regional averages are available from agencies across Canada. In Ontario, the Industry-Wide EPD Report published by Concrete Ontario provides benchmarks for various compressive strengths and exposure classes based on data from 80 facilities. The EC3 Building Transparency database and OneClick LCA are additional sources for baseline data.

Based on current market conditions, a 20% reduction below baseline is highly achievable for most applications. A 30% reduction is possible but depends on factors previously discussed including seasonal temperatures, contractor competency, and site-specific factors.

Extended Curing Time

Consider extending the days required for concrete to reach minimum strength from the typical 28 days to 56 days. This allows mixes with higher SCM content more time to develop full strength. However, Doug Hooton of the University of Toronto noted that extended curing is rarely necessary unless slag content is extremely high. Discuss with the contractor whether 56-day testing would enable different mix options for your specific project.



Workability Targets

Specify a workability target (slump range) and hold contractors accountable to it. A typical target for flatwork is 150-200mm slump. Workability affects how the concrete is placed and finished, and inadequate workability can lead contractors to add water (which ruins the mix integrity) or over-finish the surface (which causes scaling). Understanding concrete testing and what constitutes reasonable targets helps ensure specifications are both ambitious and achievable.

Shrinkage Limits vs W/C Ratios

Traditional specifications often include water-to-cement (W/C) ratio limits to control durability and shrinkage. However, W/C limits can inadvertently restrict low-carbon mix options. ASLA's Decarbonizing Specifications recommends specifying shrinkage limits (such as 0.04% for concrete pavement) instead of W/C ratios where possible. This gives suppliers more freedom to optimize their mixes while still achieving the performance that W/C limits were designed to ensure. Only include W/C limits when specifically required by the governing standard (CSA, ASI) for the exposure category.

Part IV
Quality Assurance

Quality control during installation remains a limiting factor for concrete in Ontario. Subbase preparation, batch control, finishing and curing need to be monitored and executed in a timely fashion. Unfortunately, small mistakes can result in premature failure of the concrete. This is before low-carbon options have entered the scene, resulting in reasonable hesitation from the industry. As a result of these concerns, producers limit SCM content to 25% for flatworks—not because higher percentages aren't possible, but because of repeated mistakes during installation.

The Thin Layer On Top

The unfortunate reality is that when concrete fails, it is often within the top 5mm that everyone sees while underneath the surface, the concrete is completely fine. As a result, the appearance of the top 5mm determines whether a job is deemed a success or failure. The surface layer is the most vulnerable to damage from poor installation, chloride exposure, chips and cracks, etc. The interior of a concrete slab typically achieves its required strength, but any of these cosmetic defects can be grounds to replace the concrete. Unfortunately, replacing concrete is cost prohibitive but it also doubles the carbon impact.

Concrete Placement Best Practices

Once concrete is mixed with water the chemical reaction (hydration) begins and the clock starts. The concrete should be poured in place **within one hour.** The most common problem is the addition of water to the concrete to improve workability. The risk of this increases the longer the truck has been waiting. Delivery slips are a useful tool to see when trucks left the yard so they can be monitored and turned away as needed. Adding water results in poorly mixed, uneven concrete with compromised integrity. It directly contributes to surface scaling when the surface is later exposed to de-icing agents. Adding water should never be permitted.

Resources

Graphics

Cover Image - "Man using concrete cutter" by nayukim, licensed under CC BY 2.0. Source: https://www.flickr.com/photos/nayukim/4162150602/

All internal graphics prepared by Lindsay Lane.

Documents

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