CONCRETE CARBON

A GUIDELINE FOR SPECIFYING LOW CARBON READY MIXED CONCRETE IN CANADA

CRMCA
CANADIAN READY-MIXED CONCRETE ASSOCIATION
ASSOCIATION CANADIENNE DU BÉTON PRÉPARÉ

JUNE 2024

ABOUT US

Canadian Ready Mixed Concrete Association (Concrete Canada) is a non-profit association established in 1981 to represent federally legislated issues impacting the ready mixed concrete industry and promote ready mixed concrete in Canada.

CRMCA is an association whose membership comprises each of Canada's provincial/regional ready mixed concrete associations and national cement industry, serving as a critical forum for discussion of association and industry trends and issues, codes and standards, and association programs such as environment, health & safety, promotion, marketing, education, membership, and technology.

Through its members, CRMCA provides representation in the development of national building, material and construction codes and standards developed by agencies such as Canadian Standards Association International (CSA) and National Building Code (NBC). CRMCA is a sustaining member of CSA and has representation on committees such as CSA A23.1/.2, CSA A283, CSA A3000 and Strategic Steering Committee on Concrete and Related Products.

Additionally, CRMCA members partner with national and provincial Home Builders Associations, national and provincial Construction Associations, American Concrete Institute International and local ACI Chapters, and National Ready Mixed Concrete Association (NRMCA).

CRMCA members pride ourselves in bringing education, technologies, research and innovation to architects, designers, contractors, developers, and concrete companies and continually promote concrete's sustainable advantages, benefits and evolution for society.

CRMCA
Canadian Ready-Mixed Concrete Association
Association canadienne du béton préparé

CONTENTS

CONCRETE CARBON

INTRODUCTION

Canada's Concrete Industry is a committed partner in building a low carbon world. To this end, this document provides guidance on how to specify low carbon concrete for various concrete project types.

The "embodied carbon" emissions of concrete, which are generated by the production, transportation, manufacture, and end of life disposal/recycling have been well documented by numerous sustainability professionals throughout the province. These emissions can be minimized on projects through properly defined low carbon concrete specifications. Before we dive into that aspect, the fundamentals must be understood.

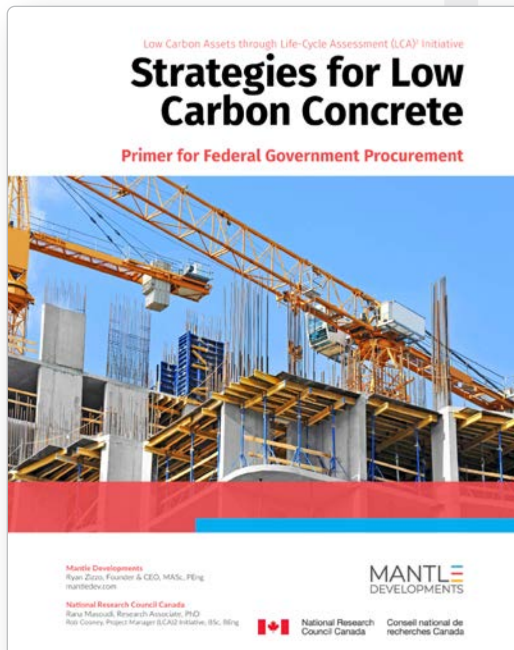
Understanding the Fundamentals

To better understand the fundamentals of cement and concrete carbon emissions, an in-depth literature review may be conducted, and resources identified, as more and more information continues to be published.

A notable resource for Canada which was derived from the Low Carbon Assets through Life-Cycle Assessment (LCA)[2] Initiative is the **Strategies for Low Carbon Concrete**, which was developed by Mantle Developments and the National Research Council of Canada (NRC). CRMCA member associations provided input into this document, and it puts a critical focus on the growing importance of embodied carbon, understanding concrete and carbon, the importance of using performance-based specifications, best practices for low embodied carbon concrete and even procurement strategies.

With buildings becoming more and more efficient through innovation and technology, the operational carbon has been significantly improved, and the construction industry and policy makers in Canada are quickly shifting their focus to specifying low carbon concrete to meet their embodied carbon reduction goals.

Incorporating the information in the document Strategies for Low Carbon Concrete, it is the intention of this guideline to provide a resource for designers and specifiers in their pursuit of carbon reductions, and more importantly, to achieve low carbon concrete for Canadian projects.



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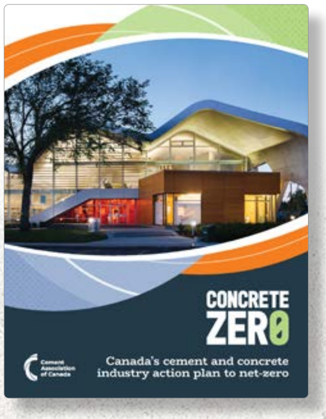
REACHING NET-ZERO

Concrete is the most widely used building material in the world. It's necessary for roads, bridges and buildings, manufacturing, renewable energy generation, resource industries, food production, and many other sectors and activities that sustain our quality of life. Concrete is durable and helps the built environment withstand the worst impacts of climate change.

The cement industry is also the world's third-largest industrial energy consumer and the second-largest industrial CO_2 emitter. In Canada, cement manufacturing accounts for 9.7 Mt CO_2, or about 1.4% of Canada's emissions, in 2020.

Across Canada there are 15 cement plants shipping cement to more than 1,100 associated facilities. Collectively, the industry supports about 158,000 direct and indirect jobs across the country and contributes $76 billion (CAD) dollars in direct, indirect, and induced economic benefit to the Canadian economy.

Canada's cement and concrete industry is committed to act and ready to collaborate to reduce the industry's emissions. Released in May 2023, **Concrete Zero: Canada's Cement and Concrete Industry Action Plan to Net-Zero** shows that emissions reductions (using a 2020 baseline) of 40% by 2030, 59% by 2040, and net-zero by 2050 are possible.



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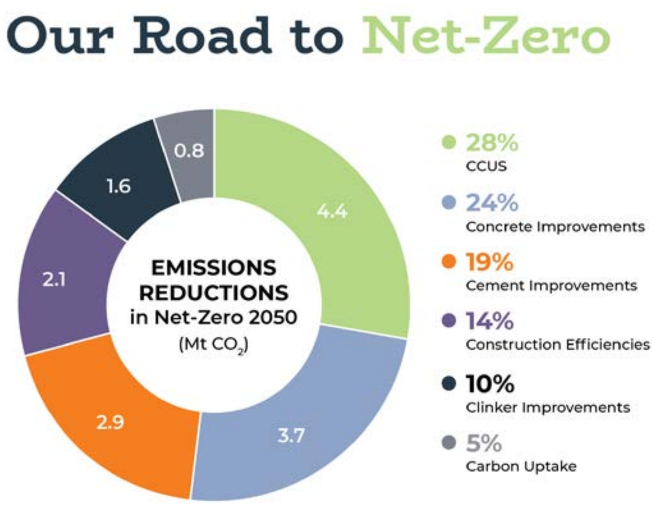
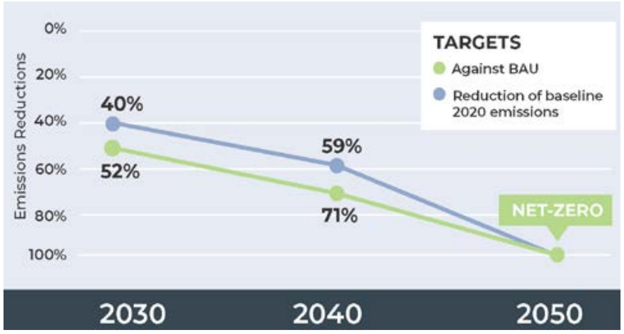
The Concrete Zero Action Plan is transparent and accountable, with progress reports to be released every five years. The plan also does not include the purchase of any offsets to meet our emissions reductions goals.

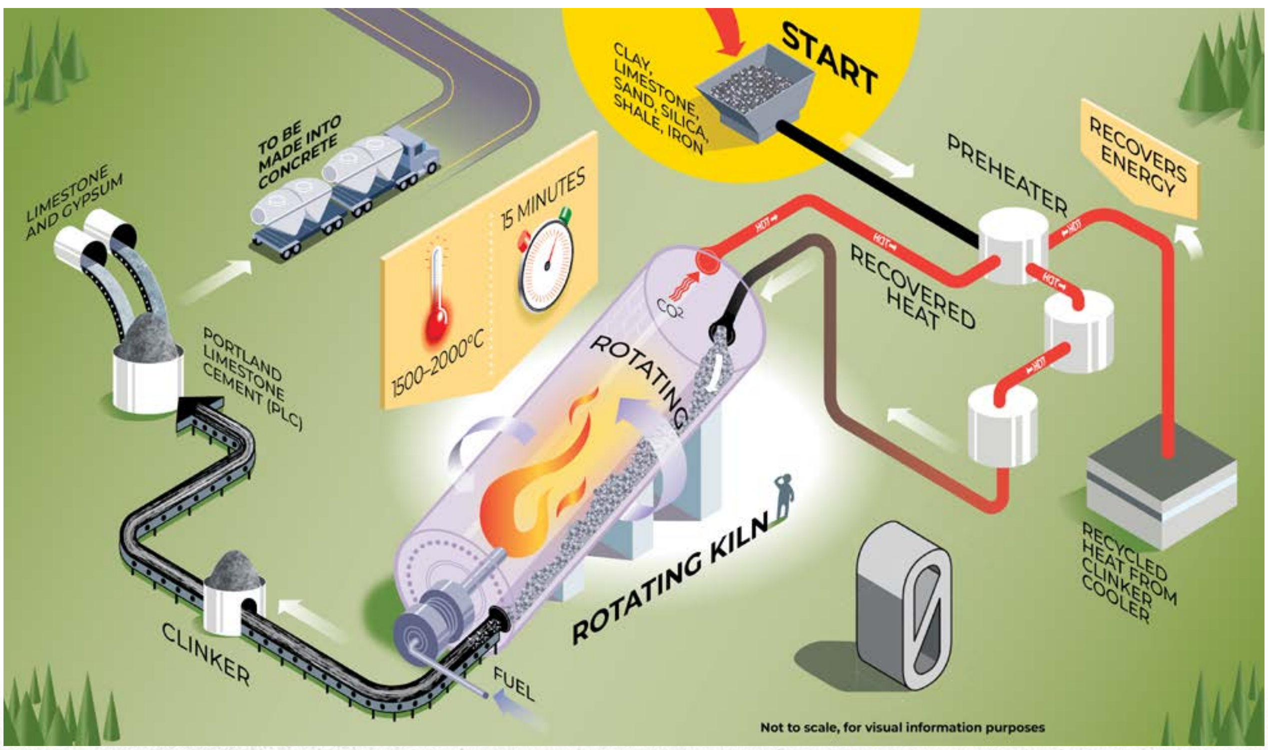
The Action Plan is based on the entire cement and concrete value chain, identifying 5 C's, for each stage where emissions reductions will come from. The 5 C's stand for: clinker, cement, concrete, construction, and carbon uptake. To reach net-zero by 2050, all stages of the value chain must be decarbonized.



There is no silver bullet, no one magic solution that will get the industry to zero. Rather, it will take many actions. In detailing the path forward, a cautious approach has been chosen in that the Action Plan uses the carbon-reduction levers available today. While the path to 2030 is clear, more research and development is needed in clinker chemistries, carbon utilization technologies, materials innovation, and clean fuel sources like hydrogen to reach net-zero by 2050.



Herein are outlined many of the steps that will be taken to reach net-zero by 2050, including reducing clinker to cement ratios, using clean fuels, deploying CCUS (Carbon Capture, Utilization and Storage), and working with partners in architecture, engineering and construction to achieve efficiency in both the design and use of concrete in infrastructure projects.



Clinker & Cement

Clinker is the key ingredient that gives cement its binding properties, it is also the most greenhouse gas-intensive component of cement and concrete. Clinker is made by heating limestone and minerals to very high temperatures (~1,500 degrees Celsius) in a rotary kiln. This process generates CO_2 through the combustion of fossil fuels to heat the kiln, as well as through "process emissions", in this case a chemical reaction of limestone that releases greenhouse gases.

In 2020, Cement Association of Canada member companies produced about 11.4 million tonnes of clinker, at an average carbon intensity of 833 kg CO_2 per tonne of clinker for a total 9.5 Mt CO_2 emissions. By 2050, the action plan projects emissions reductions from clinker to equal 1.6 Mt CO_2. There are multiple levers for reduction, including replacing virgin fossil fuels for combustion, clinker substitution by increasing the volume of blended cements produced, deploying carbon capture, utilization and storage technologies, and increasing thermal efficiency. Future opportunities also exist in the increased use of decarbonated raw materials and using novel clinker chemistries which may emerge on the market.

In Canada, fossil fuels, mainly coal, petroleum coke, and natural gas, are used for the heat needed to drive clinker production. In recent years Canadian cement manufacturers have increased their use of lower-carbon fuels, such as biomass and waste-derived fuels, that can significantly reduce combustion emissions and keep materials out of landfills. However, the fuel substitution rate in 2020 was less than 10%, well below the European average of more than 40%.

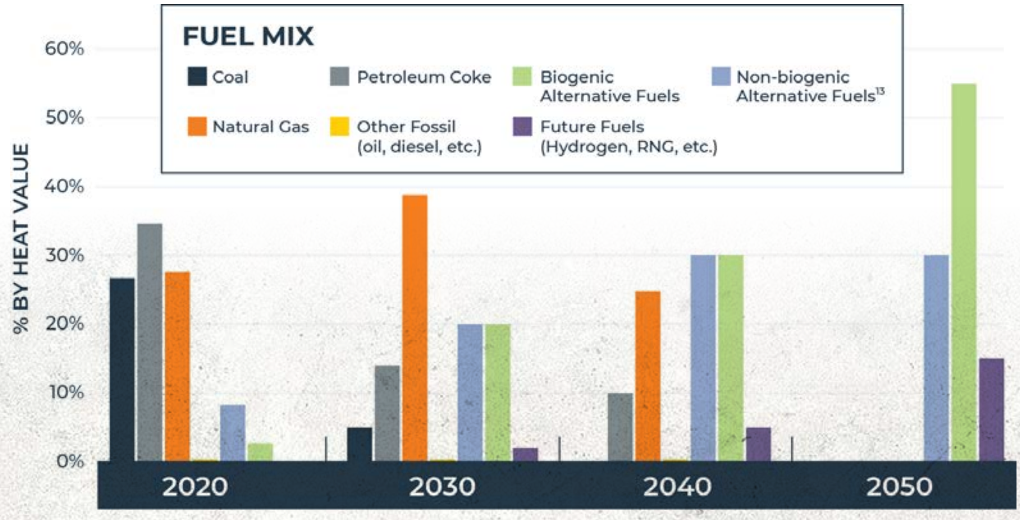
In Canada, provincial policy barriers make it difficult to obtain permits to use non-fossil-based fuels. The cement industry is working closely with provincial regulators to address these barriers, and many have recently demonstrated resolve in opening the door to deeper investment in fuel substitution in Canada.

To meet net-zero commitments, the industry will retreat from fossil fuels, starting with coal and petroleum coke, while increasing reliance on lower-carbon alternatives. By 2030, the goal is for an average substitution rate of 40%, half of which would be comprised of biomass. As higher-quality biomass fuels (e.g., biochar) and other low- or zero-carbon fuels (e.g., zero-emissions hydrogen) become commercially and economically available, the aim is to eliminate virgin fossil fuels entirely by 2050.

The most effective way to reduce total direct clinker emissions is to use less of it. This can be done by creating blended cements that utilize supplementary cementitious materials (SCMs), reducing the total amount of clinker needed to make cement.

Education and awareness across the procurement, architecture and engineering community of these new lower-clinker cements will provide certainty of performance, while government policy and incentives, like “Buy Clean” policies, will play a meaningful role in supporting market uptake.

The scale-up of Carbon Capture, Utilization and Storage (CCUS) is vital to the cement and concrete industry reaching net-zero both within Canada and globally. Commercial-scale carbon capture and storage systems can capture greater than 90%-95% of CO_2 emitted from a cement kiln. In their foundational report, **Net Zero By 2050: A Roadmap for the Global Energy Sector**, the International Energy Agency defines CCUS as an essential ‘pathway’ for heavy industry to reduce GHG emissions to avoid catastrophic climate change. The report calls for an unprecedented rate of CCUS development and deployment as part of a broader energy system transition to achieve the scale of GHG mitigation needed, including expanding global CCUS capacity from 40 Mt per year in 2020, to more than 7,600 Mt per year by 2050.



Deploying carbon capture and storage technology at full scale during cement manufacturing could eliminate process and combustion emissions almost entirely. Today, there is no other technology or process that can eliminate process emissions. CCUS, together with bioenergy, clean fuels, and carbon uptake, could result in the future delivery of carbon-negative concrete for our world.

The plans for the first net-zero carbon capture and storage facility in the North American cement industry are already underway in Edmonton, Alberta. Heidelberg Materials and the Government of Canada announced a partnership in April 2023 to develop a full-scale Carbon Capture Utilization and Storage (CCUS) facility. The new facility, which is anticipated to be operational by late 2026, will capture more than 1 million tonnes of CO_2 annually from the Edmonton cement production facility and the combined heat and power facility that is integrated with the capture process.

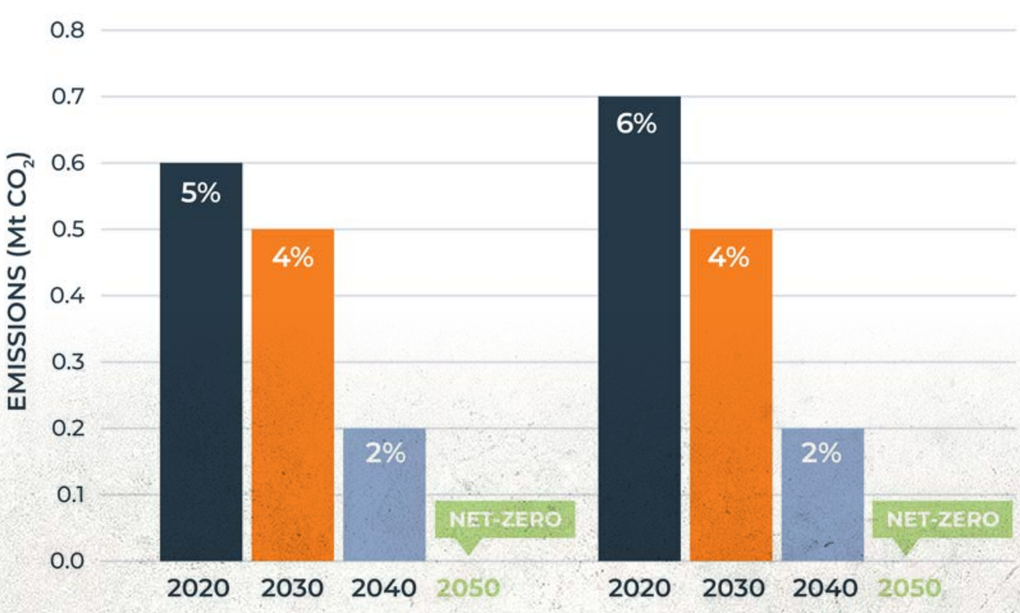
Concrete

Today, electricity consumption accounts for about 5% of the total CO_2 footprint of concrete. Shifting the energy needs of concrete production facilities to clean electricity and other low-carbon sources of energy will reduce emissions.

Delivering concrete also needs energy. While the transition to cleaner heavy-duty vehicles will take time, industrial vehicle manufacturers have made a lot of progress in powering these vehicles with clean hydrogen, electricity, and other lower-carbon fuels.

Construction

Achieving emissions reductions in construction is outside of the direct control of the cement and concrete industry and requires a shared commitment to achieving net-zero, together. We will work together with the architecture and construction industry to reduce emissions through optimization in design, and waste reduction. Just as we have done for energy efficiency, we must make material efficiency a design priority. Some examples of general strategies being promoted by the design / construction community in this regard are highlighted here. Construction optimized for waste reduction means zero waste on the job site and zero returned concrete.



General Strategies

Less is more — in concrete buildings, most of the Embodied Carbon is located within the structure. Commitment to early concept optimization and lean detailed design is critical. In addition, a few fundamental yet simple strategies can lead to significant Embodied Carbon reductions.

Consider concrete with high compressive strength

- 40 MPa concrete is 60% stronger than 25 MPa concrete
- GWP increase is only 35%

Consider steel with high tensile strength

- 500 MPa steel is 25% stronger than 400 MPa steel
- Both have similar GWP

Minimize concrete volume by maximizing reinforcement ratio for flexural members

- Nearly 100% of steel used for producing reinforcing bars comes from recycled scrap, and more than 65% of all reinforcing bars are recycled
- Slab reinforced with 0.4% vs slab reinforced with 0.2% may be 40% thinner
- 32% GWP reduction

Maximize resistance utilization by maximizing number of element sizes

- Maximizing structural utilization (i.e. resistance/demand) of each element will minimize total material volumes
- GWP values are linearly dependent on material volumes

Round up sizing in concrete elements to nearest 25 mm vs higher increments

- Adapting 225mm thick slab vs 250mm thick slab
- 11% GWP reduction

Deeper beams are more efficient than wider beams

- 400 wide x 800 deep beam is as strong as 750 wide x 600 deep
- 40% GWP reduction

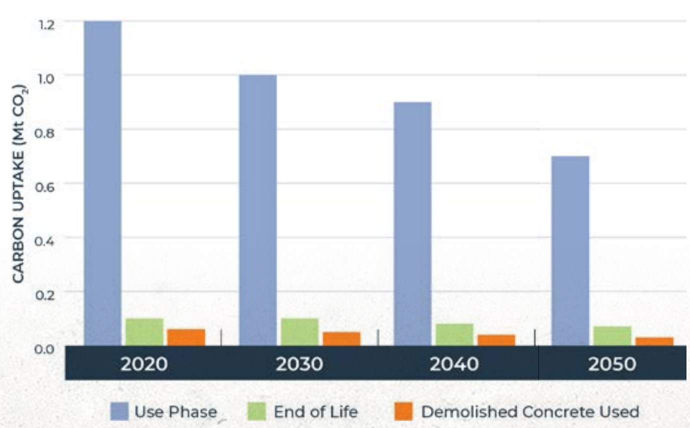
Embodied Carbon reductions listed above are examples of some specific cases, and may vary depending on actual conditions.

From: *A Pragmatic Approach to Lowering Embodied Carbon* – 2023, ZGF, Fast+Epp, Ellis Don, Lafarge

Carbon Uptake

Concrete has the ability to sequester CO_2 from the atmosphere, permanently capturing it in a process known as carbon uptake, or re-carbonation. Research conducted at **IVL, the Swedish Environmental Research Institute**, finds an average of 20% of the CO_2 calcination emissions (i.e., process emissions from clinker production) can be permanently sequestered when a concrete structure has been built.

The rate of CO_2 uptake depends on many conditions, but rates of CO_2 uptake are greatest when the surface-to-volume ratio is high, like when concrete has been crushed and exposed to air. During the design phase of a project, a good strategy to maximize CO_2 uptake is for architects and engineers to ask to use exposed concrete wherever possible.



Working with Governments

Canada's cement and concrete industry is committed to working with all levels of government to reach net-zero by 2050. There are many areas of collaboration including: research and development; codes, standards, and specifications; and procurement.

Research and development are vital to achieving net-zero, including deploying new technologies and solving technological challenges to support decarbonization. Many areas of research and development are needed, such as clean hydrogen, CCUS, and biogenic fuels.

Codes, standards, and specifications must evolve to ensure that building practices consider a changing climate and to drive made-in-Canada innovation for low-carbon materials and approaches, in addition to safety. This means "de-risking" and raising awareness of innovative solutions among designers and builders, who often favour tried-and-true methods for delivering projects on time and on budget.

Public procurement can help decarbonize construction materials. Government infrastructure projects consume about 40 percent of the cement produced around the world. The cement and concrete industry will continue to advocate for a procurement policy approach called "Buy Clean", that supports both climate and economic policy objectives by incorporating low-carbon construction purchasing requirements to address greenhouse gas emissions from construction materials in government purchasing. Concrete is the first material with a "Buy Clean" requirement under the Government of Canada's Standard on Embodied Carbon in Construction.

To sum up, there are many actions and levers needed for the Canadian cement and concrete industry to reach net-zero by 2050. There is no one solution. The industry is absolutely committed to working with all levels of government and the architectural and construction industry towards decarbonization. Together, net-zero will be achieved.

	2020	2030	2040	2050
BAU Emissions (Mt CO_2)	**11.5**[26]	**12.7**	**14.1**	**15.5**
Clinker Improvements (Mt CO_2)		0.9	1.2	1.6
Cement Improvements (Mt CO_2)		1.5	2.2	2.9
Concrete Improvements (Mt CO_2)		0.5	2.0	3.7
Construction Efficiencies (Mt CO_2)		1.0	1.6	2.1
Carbonation (Mt CO_2)		1.2	1.0	0.8
CCUS (Mt CO_2)		1.5	2.0	4.4
Net Emissions (Mt CO_2)		**6.1**	**4.1**	**(0)**

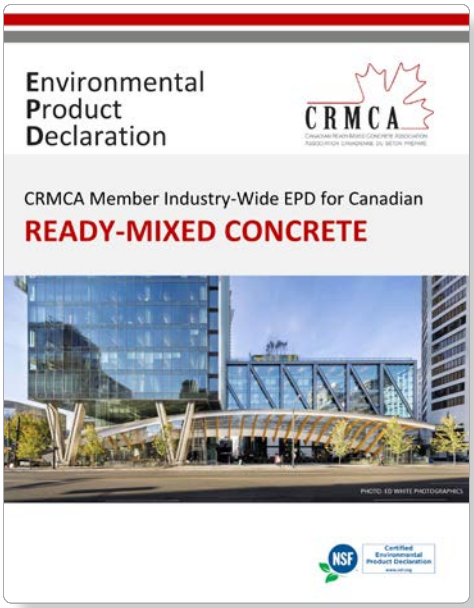
ENVIRONMENTAL PRODUCT DECLARATIONS (EPDs)

CAC Industry-Wide EPD for General Use (GU) & Portland-Limestone (GUL) Cements

In April 2023, the Cement Association of Canada (CAC) was pleased to present the Canadian and CAC member regionalized industry average environmental product declaration (EPD) for general use (GU) and portland-limestone (GUL) cements. The EPD was developed in compliance with CAN/CSA-ISO 14025 and verified by ASTM International. It includes life cycle assessment (LCA) results for the production stage or cradle-to-gate manufacture of GU and GUL cements as produced in three regions of Canada by CAC members in 2020: West, Central and East. The EPD sets out the Global Warming Potential (GWP) for GU cement as 796, 854, and 898 kg CO_2 per tonne of cement, for the West, Central and East regions, respectively. The comparable GWP for GUL cement is 732, 798, and 864 kg CO_2 per tonne of cement.

CRMCA Industry-Wide EPD for Canadian Ready Mixed Concrete

The ready mixed concrete industry's commitment to transparency of the carbon impact of specific mix designs was first introduced in 2017 with the release of the **Canadian Ready Mixed Concrete Association (CRMCA) Industry-Wide EPD for Canadian Ready Mixed Concrete**. This report was compiled by the Athena Sustainable Materials Institute and third-party verified by NSF. An Industry-Average EPD shows the environmental impacts for average concrete mixes produced in an average Canadian ready mixed plant within a specified geography. Although this information was a much-needed starting point for the industry, average Canadian information is simply not accurate enough for provincial projects. Designers and specifiers, who are in pursuit of quantifying the carbon impact for a specific mix design from a local provincial ready mixed plant, require more local data or more specifically regional EPDs.



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Regional EPD information is vital to specifying accurate low carbon concrete and with the expiration of the previous CRMCA report on January 6, 2022, the industry began to pursue 7 regional reports representing all the provinces in the country. In July 2022, all 7 regionals reports were released, and their development further exemplifies the industry's transparency and dedication to reaching the net-zero carbon concrete goal by 2050.

To access all 8 reports, please visit ASTM's website at:

https://www.astm.org/products-services/certification/environmental-product-declarations/epd-pcr.html

Provincial Association Member Industry-Wide EPD for Ready Mixed Concrete

The development of the **Regional (Provincial Association) Member Industry-Wide EPD for Ready Mixed Concrete** reports across Canada further increases the reporting accuracy of the carbon impact mix designs have on projects in Canada.

These reports were also created through Athena and third-party verified by ASTM International. A representative sample of Provincial member facilities was selected based on technical attributes, production scale, and geographic location. Provincial Association member facilities chosen by Athena to be statistically-representative on these various dynamics completed LCI data collection questionnaires.

Each Regional (Provincial) EPD features an up-to-date and accurate representation of mix designs used in the relevant market. The 2022 provincial EPDs also address some limitation that were present in the CRMCA National report from 2017. Through regional working groups of ready mixed producer representatives, along with the guidance of Athena, each region came up with locally-appropriate improvements to ensure the recently released provincial reports are even more representative of concrete in that area. Examples of some of the updates made in some regions include (contact your local provincial association for specifics on their EPD advancement):

1. Raw material EPDs are local production facilities' averages where available (national average in prior version).

2. Addition of portland silica fume cement (Type GUbSF ~ Portland cement + silica fume up to 15%) for high-strength / high-performance concretes such as 50-70 MPa and/or for classes of exposure where chloride ion permeability is required.

3. Mix designs more representative of most common concrete applications and exposure classes in accordance with CSA A23.1 and National/Provincial Building Codes.

4. Where market appropriate, specialty concrete mix designs, such as self-consolidating concrete (SCC) and/or shotcrete, added to support growing demand for architectural applications.

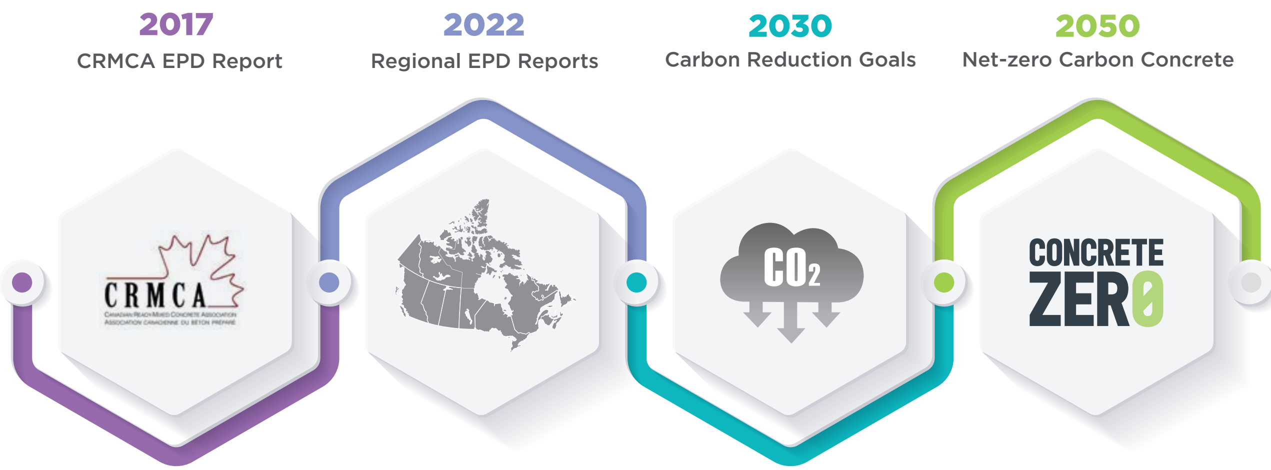
5. Additional and/or more market-specific SCM replacement levels added, including mass concrete applications for some regions.

6. Industry average baselines chosen based on representative material proportions for the region's market place. Type GU cement and/or blend of Type GU and GUL cements used for mix design baselines based on the status of that region's switchover to Type GUL.

7. Consideration given to the actual material proportioning of mix designs and the associated performance requirements of the various CSA A23.1 exposure classes to provide exceptional and important realism, connecting the EPD data to actual concrete in the field that meets CSA A23.1 and National / Provincial Building Codes.

Incorporating the noted improvements into the regional reports significantly improves the quantification of the carbon impacts on a project, and gives designers and specifiers the tools, and the confidence in those tools, required to draft specifications for low carbon concrete in Canada. The EPD reports are valid for 5 years, however an earlier update is possible if new materials and technologies become available which can significantly improve the EPDs of the mix designs.

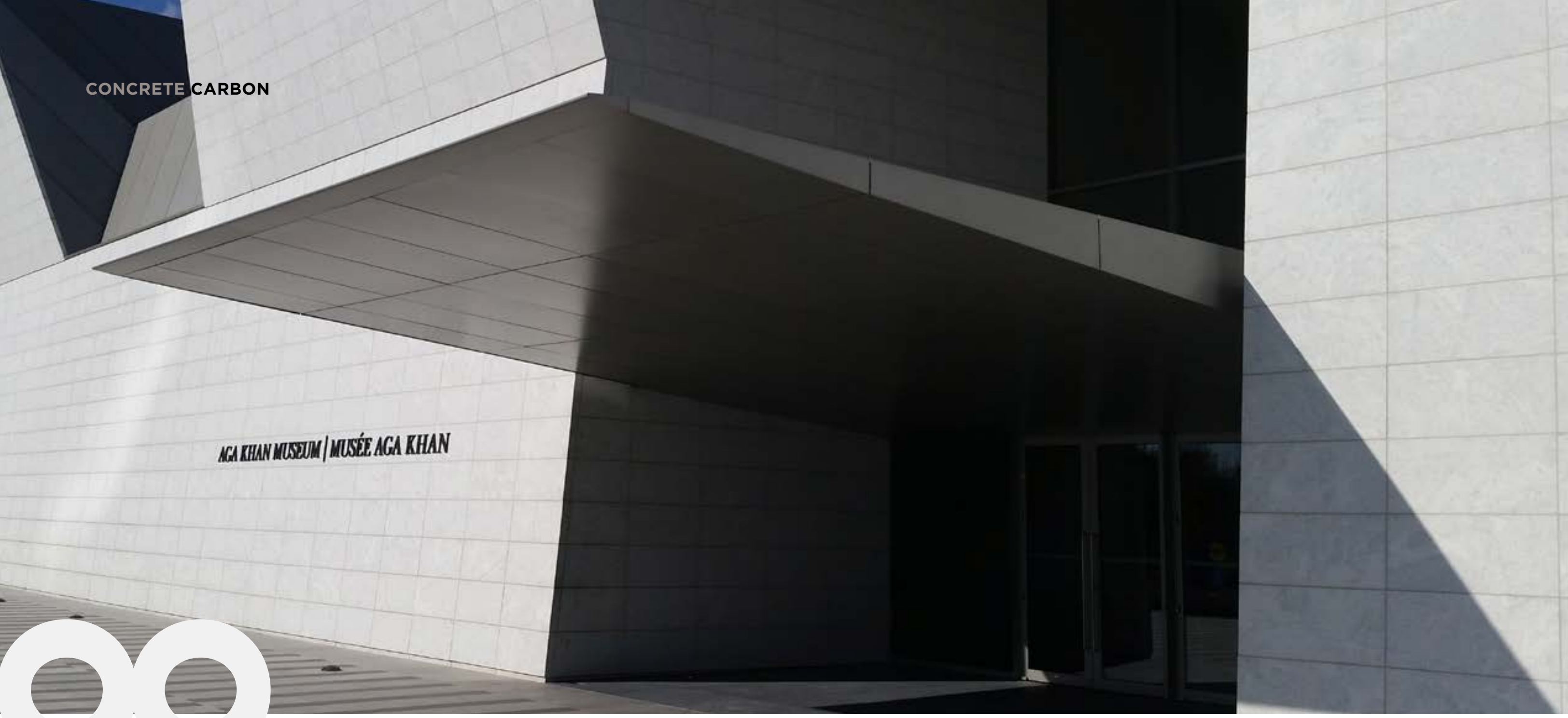
INDUSTRY CARBON REDUCTION GOALS



The 2017 CRMCA EPD report initiative started the conversation about concrete embodied carbon transparency in Canada and has since transitioned to the regional level. This transition and the usage of the 2022 provincial EPD reports have shown a significant reduction in embodied carbon of the baseline mixes and improvements will continually be made until the goal of net-zero carbon concrete is achieved. To summarize the drastic reductions that have already been achieved, the following table provides one example comparison of the CRMCA EPD Benchmarks and the more recent EPD Baselines for the province of Ontario.

CRMCA EPD Report Benchmark	Ontario EPD Report Baseline	% Reduction
25 Industry Average Benchmark with air (6% SL, 4% FA) (304.52 kg CO_2/m^3)	Baseline 25 MPa concrete with air & 0.55 w/cm (F-2) GU 10 SL (260.64 kg CO_2/m^3)	14.4
30 Industry Average Benchmark with air (6% SL, 4% FA) (349.68 kg CO_2/m^3)	Baseline 30 MPa concrete with air & 0.50 w/cm (F-1) GU 15 SL (292.72 kg CO_2/m^3)	16.3
35 Industry Average Benchmark with air (6% SL, 4% FA) (417.05 kg CO_2/m^3)	Baseline 35 MPa concrete with air GU 15 SL (334.49 kg CO_2/m^3)	19.8
40 Industry Average Benchmark with air (6% SL, 4% FA) (458.98 kg CO_2/m^3)	Baseline 40 MPa concrete with air GU 15 SL (361.65 kg CO_2/m^3)	21.2
45 Industry Average Benchmark without air (6% SL, 4% FA) (426.33 kg CO_2/m^3)	Baseline 45 MPa concrete without air GU 15 SL (349.88 kg CO_2/m^3)	17.9

The significant baseline reductions since 2017 demonstrate the possibilities available to designers to pursue their carbon reduction goals as well as the commitment of the Canadian industry to carbon transparency and the net-zero roadmap. Further reductions will be pursued for 2030 until eventually the ultimate goal of net-zero carbon concrete by 2050 is achieved.



Industry Average Self Declaration

In addition to having produced the seven regional reports, Athena also developed a basic industry average self declaration calculator (example provided) based on the data from each report. This calculator allows producers to enter their proprietary raw material information of a specific mix design, and then using industry-average material EPD information, the calculator generates a report which indicates Life Cycle Category Indicators. Although this self declaration is not classified as an official EPD, it is still an effective way to determine the impact mix designs have on a project based on industry average information. This calculator can also be used to evaluate special application impacts on a particular mix design such as accelerated strength. (example provided) Special applications will be examined in detail later on in this guide.

Although this industry average self declaration is not as accurate as a Type II or Type III EPD, there is no additional cost required to provide owners, designers, and architects more information about the impact mix designs have on their project. Allowing the usage of an industry average self declaration on a project gives specifiers a quick option for determining the embodied carbon of a concrete mix design based on already available industry average values and supports informed collaboration with their ready mixed concrete supplier to achieve their project carbon goals.

Allowing the usage of an industry average self declaration on a project gives specifiers a quick option for determining the embodied carbon of a concrete mix design based on already available industry average values and supports informed collaboration with their ready mixed concrete supplier to achieve their project carbon goals.

Athena Industry Average Self Declaration calculator example (Ontario):

Proprietary mix design information is entered into the calculator and the Life Cycle Category Indicators impact summary is calculated based on industry average EPDs.

Note: Mix proportions in a performance-based mix design are the intellectual property of the concrete producer and will not be shared with the construction team. Mix proportions are only shown in this example to demonstrate how the EPD impacts are calculated. The concrete producer will not disclose concrete proportions at any time but will provide the performance outputs of the calculator to allow the construction team to evaluate the proposed mixes.

Standard Concrete versus Baseline Example:

Concrete Ontario Mix#1 Calculator Entry

Ingredient	Amount	Units	Supplier
Portland Limestone Cement	300	kg	Ontario GUL Cement
Slag Cement	50	kg	Ontario Slag Cement
Crushed Coarse Aggregate	1,070	kg	Ontario Crushed Coarse Aggregate
Natural Fine Aggregate	800	kg	Ontario Natural Fine Aggregate
Water Reducer	150	ml	Ontario Water Reducer Admixture
Batch Water	155	L	Not Specified

Impact Summary

Impact	Units	Per m³	A1	A2	A3
Global Warming	kg CO_2 eq	281.91	88.49%	8.07%	3.44%
Ozone Depletion	kg CFC-11 eq	7.68E-06	97.61%	0.01%	2.38%
Acidification	kg SO_2 eq	1.36	73.31%	19.73%	6.96%
Eutrophication	kg N eq	0.23	90.03%	7.10%	2.87%
SFP (smog)	kg O_3 eq	23.23	62.82%	29.43%	7.75%
Non-Renewable Energy	MJ, NCV	1743.64	68.03%	19.80%	12.17%

The mix design can then be compared to the Ontario EPD report baselines through a graph and a printable report:

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In addition, if special applications will be required on the project, their impact can be quickly evaluated.

Standard Concrete

Concrete Ontario Mix#1 Calculator Entry

Ingredient	Amount	Units	Supplier
Portland Limestone Cement	300	kg	Ontario GUL Cement
Slag Cement	50	kg	Ontario Slag Cement
Crushed Coarse Aggregate	1,070	kg	Ontario Crushed Coarse Aggregate
Natural Fine Aggregate	800	kg	Ontario Natural Fine Aggregate
Water Reducer	150	ml	Ontario Water Reducer Admixture
Batch Water	155	L	Not Specified

Impact Summary

Impact	Units	Per m³	A1	A2	A3
Global Warming	kg CO_2 eq	281.91	88.49%	8.07%	3.44%
Ozone Depletion	kg CFC-11 eq	7.68E-06	97.61%	0.01%	2.38%
Acidification	kg SO_2 eq	1.36	73.31%	19.73%	6.96%
Eutrophication	kg N eq	0.23	90.03%	7.10%	2.87%
SFP (smog)	kg O_3 eq	23.23	62.82%	29.43%	7.75%
Non-Renewable Energy	MJ, NCV	1743.64	68.03%	19.80%	12.17%

Accelerated Concrete

Concrete Ontario Mix #2

Ingredient	Amount	Units	Supplier
Portland Limestone Cement	370	kg	Ontario GUL Cement
Crushed Coarse Aggregate	1,070	kg	Ontario Crushed Coarse Aggregate
Natural Fine Aggregate	800	kg	Ontario Natural Fine Aggregate
Water Reducer	150	ml	Ontario Water Reducer Admixture
Batch Water	155	L	Not Specified

Impact Summary

Impact	Units	Per m³	A1	A2	A3
Global Warming	kg CO_2 eq	330.48	90.14%	6.92%	2.93%
Ozone Depletion	kg CFC-11 eq	7.85E-06	97.66%	0.01%	2.33%
Acidification	kg SO_2 eq	1.47	75.11%	18.43%	6.46%
Eutrophication	kg N eq	0.25	91.00%	6.42%	2.58%
SFP (smog)	kg O_3 eq	24.28	64.21%	28.38%	7.42%
Non-Renewable Energy	MJ, NCV	1865.35	70.01%	18.62%	11.37%

Having the ability to provide Life Cycle Category Indicators quickly and effectively to a project is critical to allow the carbon budget to continuously be updated and analyzed. This concept will be demonstrated through an example and case study later.

Type II EPDs

Type II EPDs are self-declarations made by ready mixed producers of their mix designs and are governed by ISO 14021. Type II EPDs are not third-party verified and factor in the actual raw material EPDs that the ready mixed producer would have at their specific plant location. This provides additional transparency over the industry average values and allows designers and specifiers to achieve a more accurate representation of the carbon impact on their project. Type II EPDs are more accurate than industry average values and must be considered by designers and specifiers.

Type III Third-party Verified EPDs

Type III EPDs are governed by ISO 14025, are third-party verified and reflect the most accurate representation of a material's carbon impact from a manufacturer. More specifically, a Type III EPD provides information related to concrete from a specific mix design using plant specific carbon impact and material EPDs. As material sources for the plant change, the EPDs must be recalculated and resubmitted for third-party verification. Some Canadian Concrete producers already have Type III EPDs, and their availability can be discussed at the project level.

Athena disclaimer:
This is an automated industry average self-declaration report based on Athena's concrete LCA software and database as used to generate provincial concrete's environmental product declarations (EPDs). This document is **NOT** a Type II or verified Type III EPD. Rather, the client has entered their company specific concrete's mix design which is then compared to the appropriate regional benchmark mix based on the average provincial plant operations profile. The declared results are only informational.

WHAT IS LOW CARBON CONCRETE?

Concrete is a low carbon material compared to many other manufactured goods and is locally and responsibly sourced and used throughout the construction industry due to its structural performance, durability, versatility, and needed climate-change resiliency. Concrete technology has been advancing since its development, and as the industry continues to evolve and carbon reduction goals are better understood, the use of more advanced technologies and materials, combined with the transparency afforded by EPDs, will allow the designer to monitor, control, and optimize the embodied carbon content of their designs.

Low carbon concrete refers to concrete produced with a lower carbon footprint than traditional mix designs using baseline technology, while still meeting all relevant performance requirements. To employ low carbon concrete, specifiers, contractors, and ready mixed producers should work together to use available lower carbon impact materials and the design techniques outlined in this guideline.

SPECIFYING LOW CARBON READY MIXED CONCRETE IN CANADA

Achieving low carbon specifications is highly dependent on using the latest concrete technology and local materials with the lowest possible carbon footprint. Since concrete production materials vary across the country, each individual ready mixed producer must use their expertise, experience, and available tools to determine and batch the optimal concrete mix design. Giving the ready mixed producers the flexibility to provide concrete that meets the specified performance criteria via the use of a CSA Performance-Based Specification approach will lead to an optimized design AND a more sustainable concrete solution.

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As a starting point, the following aspects are vital to achieve an effective concrete specification:

1. **Qualification/Certification system for concrete production facilities (where available)**
2. **Designer defines performance requirements for the different concrete elements in the structure**
3. **Producer and contractor partner to ensure optimal concrete mixture is designed, delivered, and installed**

4. **Submittal and documentation of performance-based concrete mixes, delivery rates, traffic flows, washout areas, environmental and safety concerns, inspection and testing requirements, acceptance and rejection criteria, etc.**
5. **Quality assurance testing for acceptance of concrete**

6. **Clear responsibilities laid out for what to do in case of an abnormality**

Roles and responsibilities of each party involved in the project must also be understood to fully implement a concrete specification.

OWNER OR DESIGNER

Clearly specifying:

- Project roles / responsibilities (ordering, scheduling, supply, verification, testing, inspection, etc.) & interactions (preconstruction, preplacement, and progress meetings)
- Concrete requirements, ensuring structurally-sound performance
- Submittal, certification, & qualification requirements for scope of work
- Acceptance criteria, dispute resolution & change management processes
- Conducting QA to ensure requirements are met
- Identify site requirements (health & safety, power & utilities, environmental, site access, traffic flows, storage capacities, etc.)

CONTRACTORS

- Fully understand project scope and requirements
- Identify & select subcontractors and suppliers, with clear deliverables and scope of work at quote and award
- Determine initial construction schedule and methods
- Request feedback from subcontractors and suppliers regarding specification requirements and proposed scheduling
- Clarify concerns with the owner/designer
- Verify that all construction and specification issues have been addressed

Successful Concrete Specification Implementation

CONCRETE SUPPLIERS

- Identifying concrete mixtures required for the project
- Confirming exclusions and qualification to their scope of work
- Providing options for concrete performance enhancement
- Notifying the contractor of any confusing requirements
- Notifying the contractor of any prescriptive requirements that are causing non-value added restrictions in achieving strength, durability, and carbon performance-based criteria
- Perform pre-qualification testing and/or trials as necessary

TESTING AGENCY

- Complying with CSA A23.2 test methods and relevant portions of project specifications
- Ensuring personnel and equipment meet requirements of CSA A283 or CAN/CSA-ISO 9001 with equivalent scope to CSA A283.
- Assign CCIL-, ACI- or equivalent certified technicians for all field testing
- Use CCIL-certified or CAN/CSA-ISO 9001 laboratories for concrete testing
- Notifying the contractor of perceived issues, requirements for specimen storage, initial cylinder curing, etc.
- Informing the site representative and concrete supplier of plastic test results
- Distribution of test reports to all parties involved in a timely manner, especially the Concrete Supplier

Performance-Based Specifications

It is the responsibility of the specifier to clearly outline the performance criteria that must be met by the contractor and ready mixed producer on any given project.

These responsibilities are clearly defined in CSA A23.1 - Concrete materials and methods of ready mixed concrete construction Table 5 and must be followed if success is to be had in specifying low carbon concrete.

PERFORMANCE

Performance-based specifications offer the specifier the ultimate peace of mind that the ready mixed producer is responsible for the performance of the concrete as delivered.

They also give the ready mixed producer flexibility in optimizing mix designs.

This flexibility becomes critically important when a ready mixed producer needs to use multiple CSA-approved approaches in designing mixes to meet a variety of requirements including strength, durability, constructability, and carbon/sustainability.

Performance-based specifications are critical to specifying and achieving low carbon concrete.

PRESCRIPTIVE

It is highly discouraged to specify any mix proportions, including material quantities (e.g., admixtures, aggregates, cementitious materials, and water), as the mix design becomes prescriptive, and the owner assumes full responsibility for the concrete performance.

Using prescriptive mix designs can not only negatively impact the performance of the concrete but can also very likely negatively impact the realization of carbon reduction goals on the project since the specifier will not be aware of the raw materials used by each individual concrete producer or plant.

Low Carbon Concrete Specification Considerations

1 ✓ Required structural criteria, including strength at age (e.g., 35 MPa at 56 days)

Strength at Age Design

If the project schedule is flexible, designing the concrete for the strength at a maximum allowable age gives the ready mixed producer the option to minimize the quantity of cement used (e.g., Type GU, GUL, GUb-SF, etc.) and maximize the usage of supplementary cementitious materials (SCMs - slag, fly ash, etc.). This in turn creates a more sustainable, overall lower carbon concrete.

For example, concrete is typically designed to achieve a strength target within 28 days, but if the structural element that is being constructed is not being put into service within that time frame, the design strength at age can be pushed until 56 days or even 91 days. For instance, under CSA A23.1 Table 2, C-1 class concrete is required to achieve 35 MPa within 56 days to ensure all other performance criteria can be met, including a chloride ion penetrability requirement of <1500 coulombs within 91 days.

Specifiers should make the determination of when elements will be put into service and whether the schedule allows for extending the age at which the strength must be achieved.

2 ✓ Required durability criteria, including class of exposure (e.g., Maximum 0.40 w/cm, Class C-1)

Classes of Exposure

Classes of exposure, as defined in CSA A23.1 Tables 1 and 2, identify the environment that a concrete will be exposed to and must be used by owners to clearly outline the performance requirements. For example, if a concrete will be used for an interior application (Class N) such as an interior wall, it is understood that this concrete will not be exposed to chlorides, freezing and thawing, sulphates, and so forth for the duration of its service life. On the other hand, if the application is an exterior sidewalk, Class C-2 would be applicable, and the concrete would be non-structurally reinforced (i.e., plain) and will likely be exposed to chlorides and freezing and thawing. Owners must understand the fundamental difference between the classes of exposure to ensure that the correct concrete will be used.

Since ready mixed producers must adhere to the classes of exposure requirements and the corresponding maximum water to cementitious ratios (w/cm), it is critical for the specifier to choose the most applicable classes of exposure for each element. Over-specifying will increase the embodied carbon content of the mix design and will limit the ability of the ready mixed producer to supply low carbon concrete.

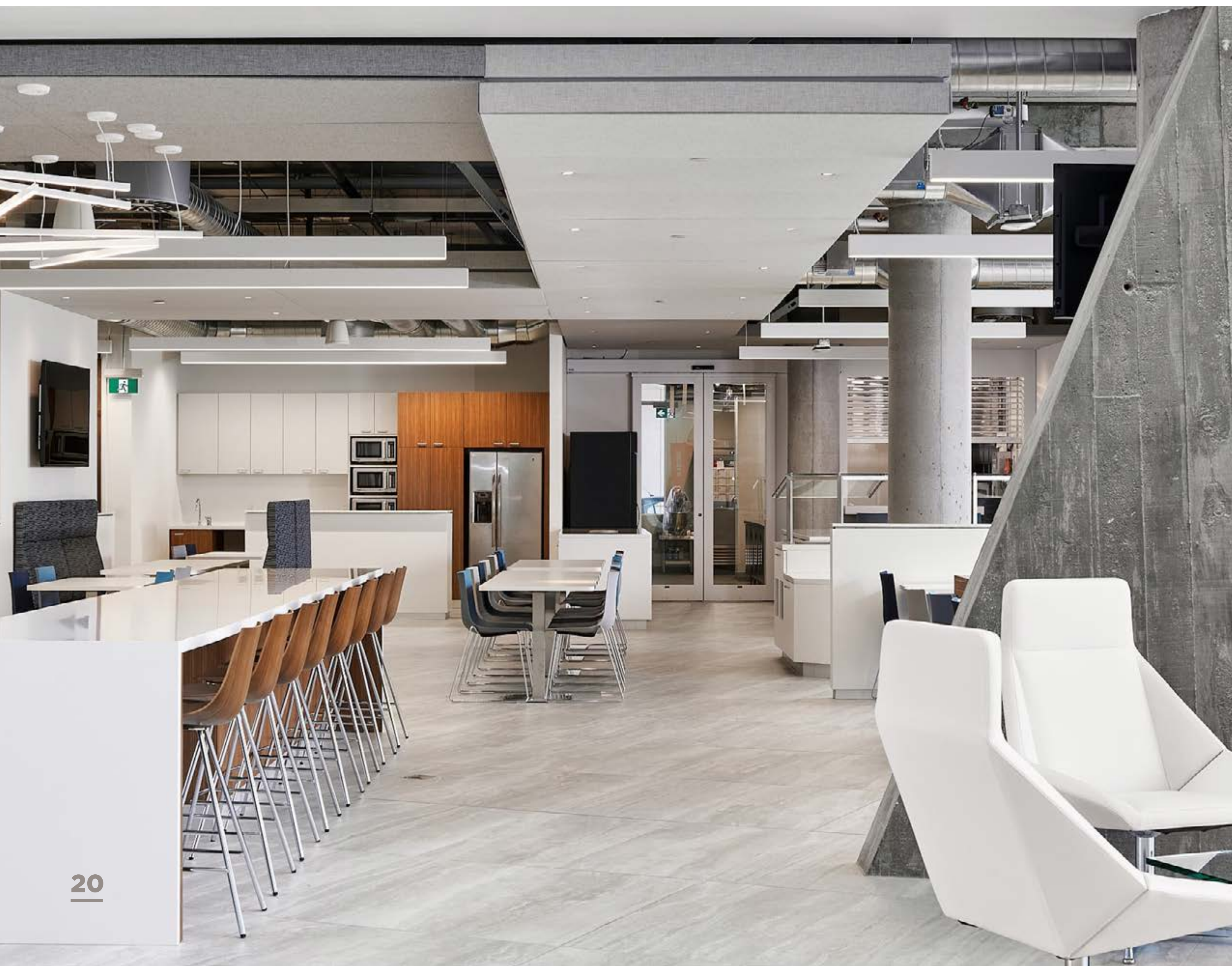
For example, as shown in **Figure Class C-1 VS. Class F-1**, if a structurally reinforced mass concrete foundation will be exposed only to freezing and thawing and not to chlorides, then the correct classification would be an F-1 class of exposure, instead of the commonly assumed C-1 class of exposure. The structural requirement for the project might still be 35 MPa, but the maximum allowable w/cm would be 0.50 instead of 0.40, giving the ready mixed producer the ability to formulate a much less carbon intensive mix design.

CLASS C-1 VS. CLASS F-1

Ontario IA EPD report

2.1% GWP decrease

Environmental impacts	35 MPa concrete with air & 0.40 w/cm (C-1) GU 25 SL	35 MPa concrete with air GU 25 SL
GWP kg CO_2 eq.	313.07	306.42

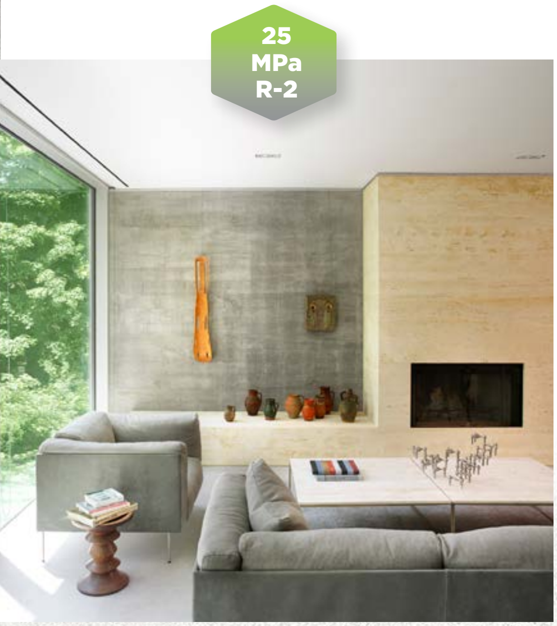


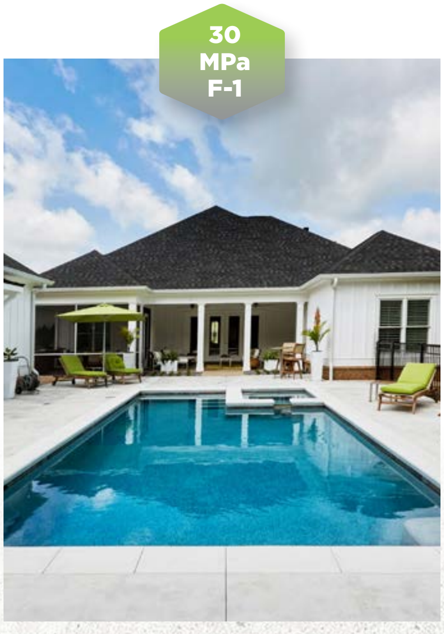
During the design phase, the specifier must give due consideration to the correct classes of exposure. The following are typical class of exposure examples from the Atlantic Industry-average EPD report:

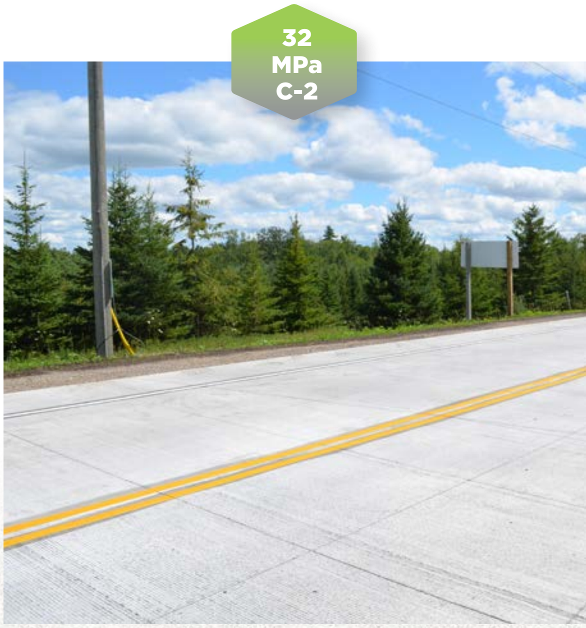
GWP IMPACT OF INCREASING EXPOSURE CLASSES

Atlantic IA EPD report

25 MPa concrete with air & 0.55 w/cm (F-2) GU	30 MPa concrete with air & 0.50 w/cm (F-1) GU	32 MPa concrete with air & 0.45 w/cm (C-2) GU
401.32	428.18	477.15
Exterior Walls and columns	Pool decks, patios, tennis courts, freshwater pools, and freshwater control structures	Garage floors, porches, steps, pavements, sidewalks, curbs and gutters







It should be noted that if multiple classes of exposure are specified, the most stringent requirements must be followed.

3 Additional criteria for durability

Some concrete elements have specialized durability requirements beyond those defined by the typical exposure classes of CSA. These criteria can include exceptionally long service lives, more sophisticated testing such as direct abrasion resistance, salt scaling slabs, depth of chloride penetration, flexural strength, or resistance to other conditions such as abnormal temperatures or exposure to specific chemicals.

These requirements can necessitate the use of specialty materials or design considerations, and when it comes to integrating such criteria, it will serve the designer well to remain aware that anything driving a need for increased cement contents will increase the carbon impact of the concrete. Such design and testing can take considerable time and labour, and special requirements should be identified up front to ensure that the process can be completed and that mix designs are optimized for both performance and carbon intensity based on the results.

Use of a performance-based specification that fully allows the producer to leverage all available tools, techniques, and technology to develop appropriate mix designs is even more critical to projects of this nature.

4 Volume stability

Low-shrinkage Concrete

Low-shrinkage concrete requires the use of special mixture proportions, materials, and/or shrinkage-reducing admixtures which result in drying shrinkage less than that of normal concrete. As per CSA A23.1, low-shrinkage concrete is defined as concrete where the shrinkage after 28 days of drying (at the concrete age of 35 days) is not greater than 0.040% if prisms with a cross-section of 75 × 75 are used.

To achieve these results, larger aggregate sizes, lower water to cementitious ratios, and potentially specialty admixtures are needed to reduce the shrinkage of the concrete. In turn, these performance enhancements and consequent mix design formulation changes may impact the carbon reduction goals of a project. Commonly low-shrinkage concrete is specified for wastewater treatment facilities and if it is required, owners must factor in their impact on the overall project carbon.

5 Architectural requirements (e.g., Colour, surface finish, etc.)

Architectural Concrete

Architectural concrete not only needs to meet the typical performance criteria of standard concrete but is also distinguished by having an aesthetic requirement. The aesthetic aspect may require a specialty type of concrete, placement method, or even unique forms to achieve the desired look. Commonly, self-consolidating concrete (SCC) and shotcrete are used for architectural concrete purposes, and both mix designs often require an increase in the cement content or even a special cement type like Type GUb-SF. The benefits of using SCC, for example, must be put into perspective to fully understand the complexity and importance of this mix design. Several advantages include:

- SCC is designed to flow and consolidate on its own, which makes it particularly useful where placing conditions are difficult or complex geometries are required.

- SCC offers superior ease of placement and workability, which results in faster placement rates with less effort and can contribute to reductions in project timelines, equipment, labour, rework, and cost. Wear and tear on equipment is reduced, as are noise levels and vehicular emissions, and there is a reduced risk of worker strain and injury.

- SCC mixes have better consolidation and bond with reinforcement and other embedded elements. This provides greater flexibility for innovative structural and architectural designs, shapes, and finishes.

- SCC mixes typically have superior performance for both strength and durability. This can result in design with smaller members, better able to resist stresses and less overall material consumption.

Due to all these additional benefits over standard concrete, the carbon impact of SCC mix designs is increased, and must be factored into the carbon reduction goals. To give designers a better understanding of the impact of these specialty mixes, some of the updated 2022 provincial EPD reports feature Industry-Average mix designs for SCC and/or shotcrete. Industry-Average mix designs for both SCC and shotcrete.

6 Sustainability (e.g., Maximum Global Warming Potential limits in kg·CO_2 /m^3)

Global Warming Potential (GWP) Limits

Specifying GWP limits for concrete mix applications is a new performance requirement which is slowly being phased in as specifiers and the industry continue to further understand the impact mix designs have on a project. The provincial Industry-wide EPD report includes GWP baselines for specific mix designs that constitute a good starting point to be used by designers and specifiers to outline GWP targets for applications on a project. There are challenges associated with just specifying GWP limits for concrete applications and elements as an overall carbon reduction goal on a project, which will be addressed later in this guideline through a case study. The concept of a **Concrete Carbon Project Budget (CCPB)** will be showcased in the case studies at the end of this guide and will systematically look at standard and special application concretes' impact on the overall concrete carbon budget.

7 Pre-qualification or verification criteria (i.e., Compressive strength results)

The use of prequalification or verification criteria is common for non-standard concrete construction or where there are unique combinations of performance needs. Many designers already request submission of prequalification data to ensure that proposed concrete mix designs will perform as needed for strength development over time, durability, and/or architectural needs. When it comes to specifying lower carbon concrete, the same approach can be applied, where the designer may specify submission of performance data, and/or mock-up trials to verify that mixes meet the necessary requirements, and where the corresponding carbon impacts of those mixes can be evaluated.

8 Quality management requirements

A strong quality management system is key to ensuring a successful project, whether looking at the project deliverables or its sustainability. True quality management is not just a testing program – a holistic approach to systems and process management of the entire project must be adopted to realize any benefit. Investing in and supporting good quality control and assurance practices on a project is a must for the reduction of waste materials, time, and resources. A commitment by all parties involved to robust Quality Management means that the concrete will be properly specified, qualified, placed, tested, protected and cured, and put into service right the first time, minimizing the amount of waste and the associated carbon impacts.

The concept of a Concrete Carbon Project Budget (CCPB) will be showcased in the case studies at end of this gui and will systematically look at standard and special application concretes' impact on the overall concrete carbon budget.

CONCRETE CARBON

Clearly outlining the submittal and performance requirements, carbon goals, prequalification requirements, acceptance and rejection criteria, corrective actions and change management plans, verification processes, and dispute resolution procedures ensure that the designer, contractor, testing agency, and ready mixed producer are aligned with the proper protocols to follow.

Communication channels must also be identified and open to ensure efficient notification, sharing, and processing of information. For example, sharing test reports immediately with the producer and contractor can help to efficiently identify potential issues or opportunities to allow for on-site optimization.

Likewise, improper scheduling, estimating, on-site labour and resource allocation, and last-minute change requests can result in confusion, project delays, excess waste and emissions, increased safety factors, potential safety hazards, and insufficient information to make optimal decisions. In particular, the importance of following all CSA testing standards in the field and laboratory cannot be overstated as proper, accurate, and timely testing and reporting is necessary to ensuring the reduction of overdesign, reduction of unwarranted waste, and the reduction of the associated carbon impacts of both. Preplacement and routine progress update meetings are essential to ensuring effective communication and that issues and opportunities are identified and addressed.

Particular attention should also be paid to change management. As materials and environmental conditions vary over time, minor adjustments to mix proportions may be required to maintain consistency. Likewise, if a mix design is overperforming, there may be opportunity for the producer to optimize their designs. As such, minor adjustments should be allowed, without time consuming and costly requalification, to maintain flexibility and to optimize performance and carbon.

When the designer, contractor, ready mixed producer, and testing agency are all following CSA standards and committed to best practices for quality assurance and control, a solid foundation for the true delivery of a lower carbon concrete project is in place.

In particular, the importance of following all CSA testing standards in the field and laboratory cannot be overstated as proper, accurate, and timely testing and reporting is necessary to ensure the reduction of overdesign, unwarranted waste, and associated carbon impacts of both.

9 Whether the concrete supplier shall meet certification requirements of concrete industry certification programs (i.e., Plant and/or truck certification)

Plant and/or truck certification

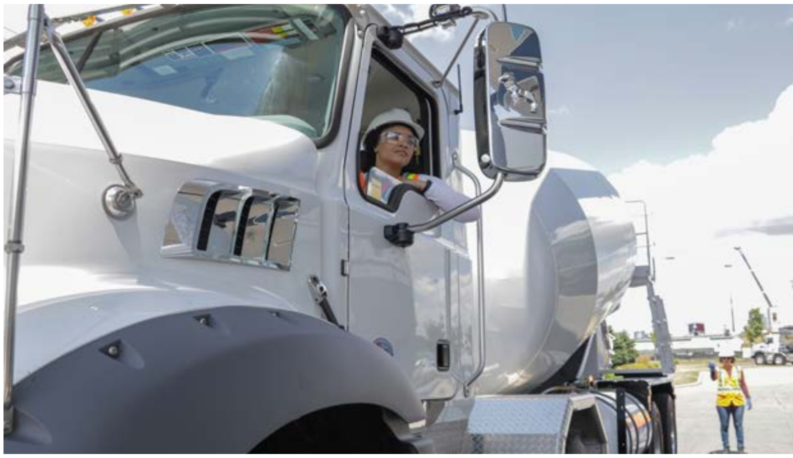
One way to assess consistency in mix design batching and delivery is by specifying adherence to an industry certification program in regions where such programs are available. These programs ensure that all the equipment, plants, and for some programs, trucks, meet the same industry standards which provides a level playing field for all certified producers and consistency of material delivery for owners. In addition, some jurisdictions also offer ECO certifications.

Having specifiers indicate a requirement of plant and truck certification, where available, is therefore helpful in achieving low carbon concrete.

Provinces / Regions with plant / truck certification programs provide full current certification lists on their respective website

10 Any other properties that might be required to meet the owner's performance criteria

At times, other considerations may arise outside the scope of what has been discussed already within this document regarding additional properties that might be required for specialty applications, such as lightweight concrete, high density concrete, underwater placement, pervious concrete, use of innovative materials or technologies, and so forth. In such cases, the concepts discussed in previous sections may be applied, where the performance requirements should be clearly identified up front and discussed with all stakeholders in order to evaluate material, design, and placement options, the associated scheduling and carbon impacts, and the best path forward to a lower carbon solution.



Concrete Raw Materials

Limiting the use of certain concrete raw materials and their quantities is considered prescriptive and goes against the fundamental approach of performance-based specifications. A far superior approach is to allow the use of already proven and standardized materials and give the ready mixed producer the option to determine what is required to meet the specified performance. As with many other industries, supply chain challenges have also been experienced by ready mixed producers in Canada and communicating performance-based requirements and allowing the producers to optimize their materials will minimize any problems in achieving low carbon concrete.

A far superior approach is to allow the use of already proven and standardized materials and give the ready mixed producer the option to determine what is required to meet the specified performance.

Cement Type

The most significant contributor to the carbon impact of concrete comes from the cement, and, as such, selecting the least carbon intensive cement available will lead to the least carbon intensive concrete. Specifying a cement type becomes prescriptive as availability from producer to producer varies across the province and therefore all available cements certified in accordance with CSA-A3001, Cementitious Materials for Use in Concrete, should be allowed. A notable mention is portland-limestone cement (PLC) which reduces the carbon impact of regular portland cement (PC) by up to 10% through a one-to-one replacement. The reduction in CO_2 emissions is realized by intergrinding up to 15% limestone with clinker to produce GUL cement instead of regular GU cement, which traditionally has incorporated up to 5% interground limestone.

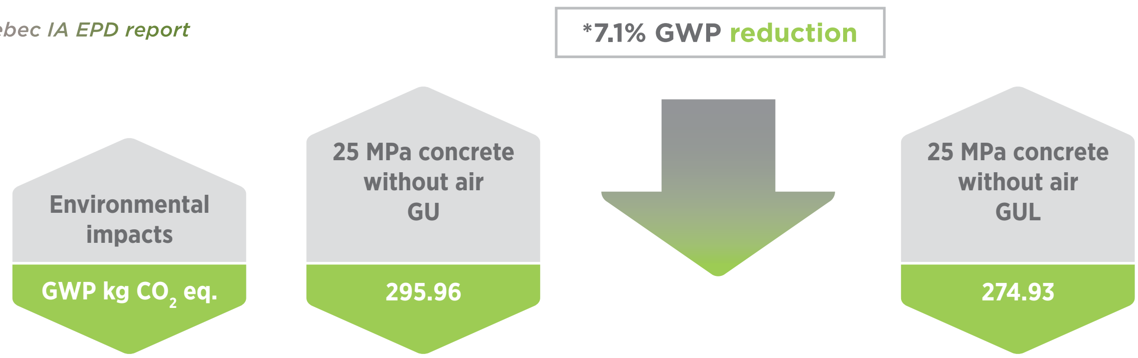
Process and combustion emissions are thereby reduced by up to 10% for GUL cement while still producing concrete of equivalent performance to GU base mixes, including comparable strength and durability. There are several PLC cement types available for different applications, but the most commonly used is Type GUL or General use portland-limestone cement. GUL cement will be replacing the traditional Type GU cement which is already being phased out across Canada. PLC is widely accepted in Canada, including in the majority of provincial and municipal applications and its use is highly encouraged by the ready mixed industry to specifiers to achieve a low carbon concrete.

The cement industry is constantly working in reducing their CO_2 emissions, thus GWPs are evolving as improvements are made by manufacturers at each individual plant. The provincial industry average EPD use the average of most of the cement producers in that province at a specific point in time.

For example by consulting the provincial EPD reports and looking at the GWP values for GU versus GUL, the savings become evident, as highlighted in **Figure GU VS. GUL**.

GU VS. GUL

Quebec IA EPD report



*Cement makes up approximately 80 to 85% of the concrete CO_2 footprint so the resulting GHG savings in the concrete does not equal 10%. In addition, the soon to be developed 2022 cement LCI data will show the cement plants are closer to the 10% reduction in the CO_2 emission than the 2020 data this calculation is based on.

For further information about PLC, the Cement Association of Canada's PLC Compendium, **A Technical Introduction to Portland-Limestone Cement**, can be reviewed which features an in-depth look at PLC performance and a collection of projects where it has already been utilized successfully.

Download PDF Document

Supplementary Cementitious Materials (SCMs)

Supplementary Cementitious Materials (SCMs) provide a multi-faceted impact on the long-term performance of concrete and achieving carbon reductions. In Ontario, slag SL is the most commonly used SCM and since it is a by- product from the steel industry, its inclusion has a beneficial impact on concrete's embodied carbon content. Pending the source, when SL is used in concrete it can provide various other performance benefits. Both slag and fly ash are common in Quebec.

*Benefits may vary with type and source

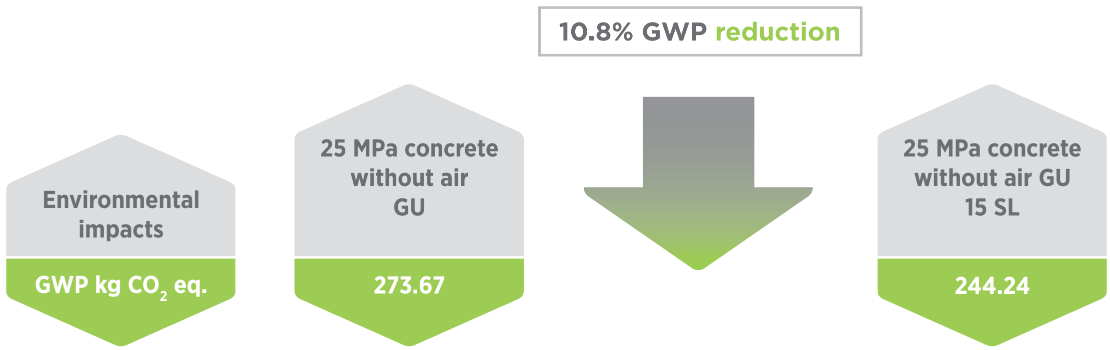
Fly ash has been bringing most of the same benefits as slag to the performance, durability and resilience of concrete for decades and is the main SCM to bring carbon reduction in concrete in Western and Atlantic Canada. Though most power generating facilities have phased out or are phasing out the use of coal across the country, vast reserves of historical production are now being harvested in Western Canada. Thanks to the current evolution of fly ash beneficiation processes, the fly ash of today and the future will continue to meet CSA 3000 and A23.1 requirements, bringing continued consistent concrete performance, durability and resilience, with a lower carbon footprint.

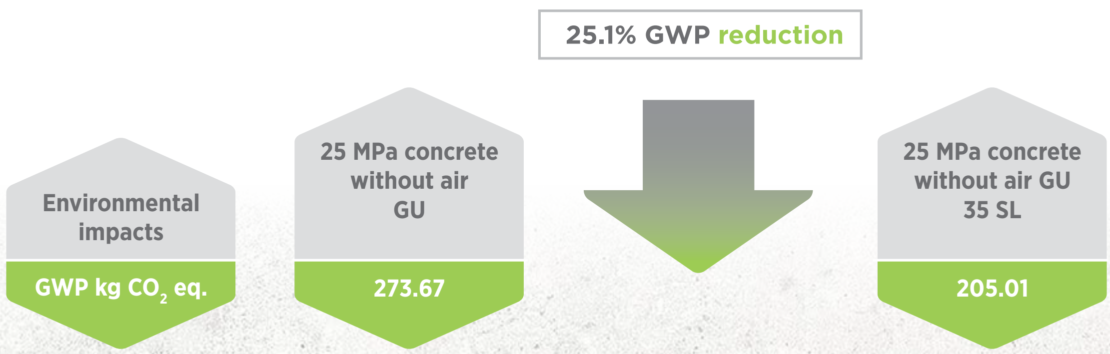
Natural pozzolans are also entering various markets in Canada, bringing many of the same benefits, including carbon reduction, as slag and fly ash to the concrete industry.

Silica fume, added neat as an SCM concrete ingredient or in a blended cement such as GUb-SF, is also available and is primarily used for high strength and high-performance-concrete. The examples below demonstrates that the more SL or FA is used in concrete mix designs, the lower the GWP value of that concrete becomes in terms of kg CO_2 /m^3.

INCREASING SLAG REPLACEMENT

Ontario IA EPD report

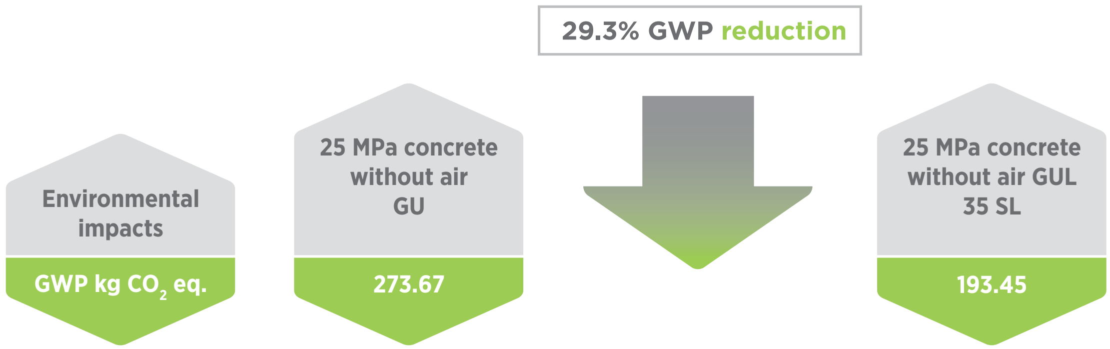




This reduction is even more evident when SL or Fly Ash is paired up with GUL compared to the GU mix designs, as shown in **Figure GU VS. GUL + SLAG** and **Figure GU VS. GUL + Fly Ash.**

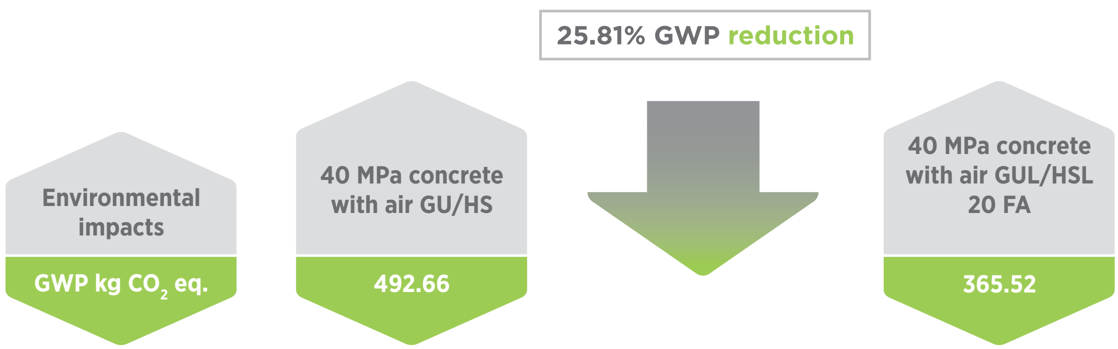
GU VS. GUL + SLAG

Ontario IA EPD report



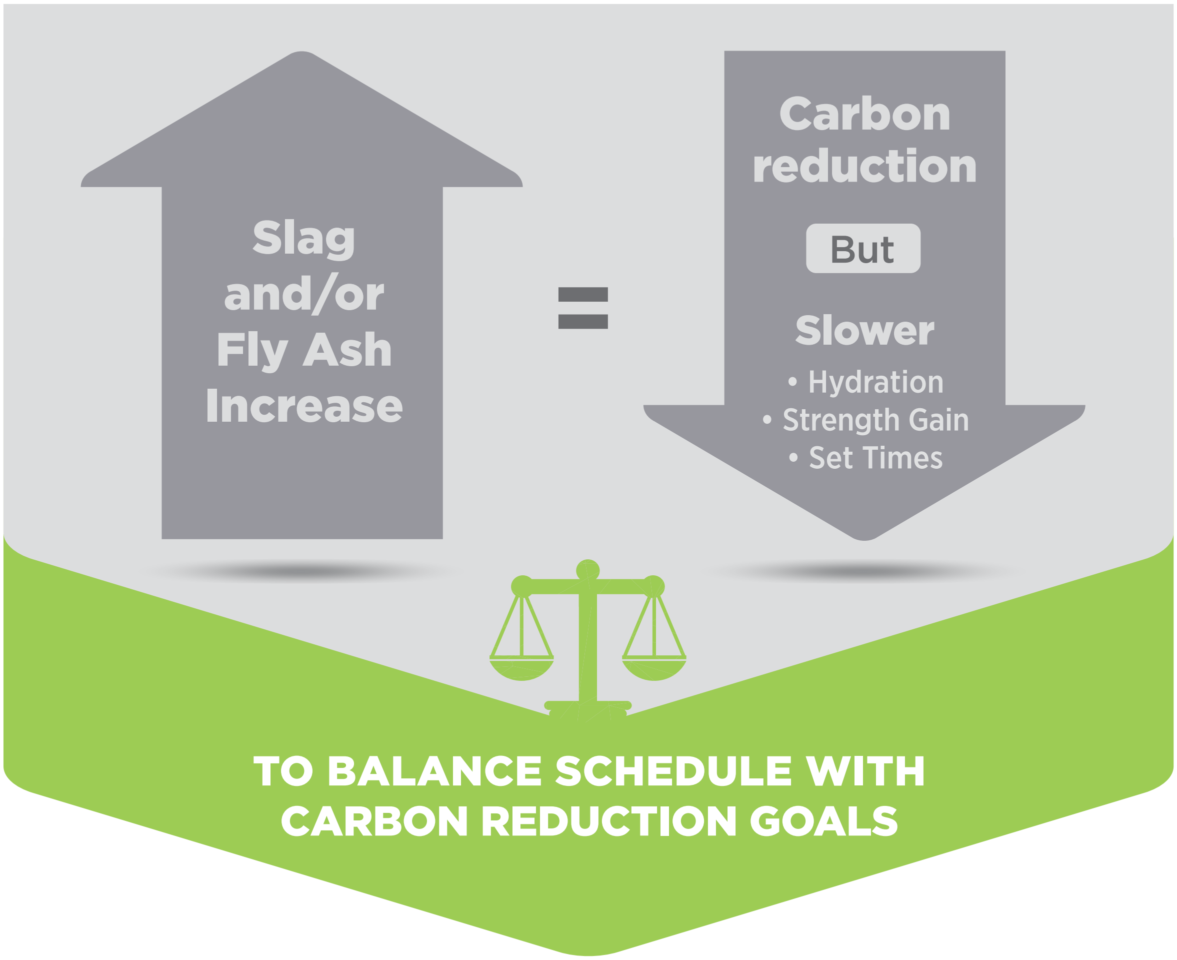
GU VS. GUL + FLY ASH

Alberta IA EPD report



Not only do SCMs improve the sustainability of the concrete, but they must also be used to achieve certain performance criteria such as the chloride ion penetrability requirements for certain classes of exposure like the mandatory performance requirement for Class C-1 concrete of < 1500 coulombs within 91 days.

An alternative approach to achieving the coulomb rating is to use Type GUb-SF. It can be used without other SCMs as the pre-blended silica fume is able to lower the overall permeability of the concrete.



- ✓ Review project schedule opportunities
- ✓ Prequalification testing of mixes
- ✓ Trials testing of mixes
- ✓ Additional curing needs
- ✓ Maturity testing during construction

Additional Curing

The curing of concrete is the maintenance of a satisfactory moisture content and temperature for a period of time immediately following placing and finishing so that the desired properties may develop. Adequate curing of concrete cannot be overemphasized, and is a fundamental component of concrete construction. Proper-curing will increase durability, strength, watertightness, abrasion resistance, volume stability, and resistance to freezing and thawing and chlorides. It should go without saying that any carbon reduction strategy should also be committed to CSA and building code best practices that ensure good useful life of concrete construction.

achieve the performance criteria outlined by the relevant classes of exposure. This relates back to the concept of most SCMs generally slowing down the overall rate of reaction where additional curing may need to be provided to achieve equivalent maturity and the desired performance criteria. n some situations, more advanced curing methods such as wet curing may be required to maintain the necessary moisture within the concrete, particularly at lower w/cm ratios.

No matter the volume of SCMs being used, proper curing is essential for durable, quality concrete construction. All specifiers will do best service for

Proper curing will increase durability, strength, watertightness, abrasion resistance, volume stability, and resistance to freezing and thawing and chlorides. It should go without saying that any carbon reduction strategy should also be committed to CSA and building code best practices that ensure good useful life of concrete construction.

The allowable curing regimes are defined in CSA A23.1 Table 19 and the Curing Type is dependent on the classes of exposure and the volume of supplementary cementitious materials (SCMs) used in the mix design. The greater the percentage of SCMs incorporated into the mix design, the longer the curing period must be to

their clients by referring to Table 2 in CSA A23.1 to ensure they are specifying appropriate curing regimes for the exposure class and SCM-level (Normal concrete, HVSCM-1, HVSCM -2).

HVSCM - High-volume supplementary cementitious materials.

CSA A23.1 – TABLE 19 – ALLOWABLE CURING REGIMES

Curing Type	Name	Description
1	Basic curing	3 d at ≥ 10°C or for the time necessary to attain 40% of the specified strength
2	Additional curing	7 d total at ≥ 10°C and for the time necessary to attain 70% of the specified strength
3	Extended wet curing	A wet-curing period of 7 d at ≥ 10°C and for the time necessary to attain 70% of the specified strength. The curing types allowed are ponding, continuous sprinkling, absorptive mat, or fabric kept continuously wet

For example as per CSA A23.1, Table 2, depending on the classes of exposure, normal concrete can be required to meet basic, additional, or extended wet curing. HVSCM-2 primarily is required to meet additional curing and HVSCM-1 is a combination of additional and extended wet curing.

CURING (NORMAL CONCRETE)

Ontario IA EPD report

Environmental impacts	Baseline 35 MPa concrete without air GU 15 SL
GWP kg CO_2 eq.	295.46

Required curing: Basic curing

3 d at ≥ 10°C or for the time necessary to attain 40% of the specified strength.

CURING (HVSCM-2 CONCRETE)

Environmental impacts	35 MPa concrete with air & 0.40 w/cm (C-1) GU 42.5 SL
GWP kg CO_2 eq.	262.87

Required curing: Additional curing

7 d total at ≥ 10°C and for the time necessary to attain 70% of the specified strength.

CURING (HVSCM-1 CONCRETE)

Environmental impacts	35 MPa concrete with air & 0.40 w/cm (C-1) GU 50 SL
GWP kg CO_2 eq.	241.35

Required curing: Extended wet curing

A wet-curing period of 7 d at ≥ 10°C and for the time necessary to attain 70% of the specified strength. The curing types allowed are ponding, continuous sprinkling, absorptive mat, or fabric kept continuously wet.

CONCRETE CARBON

LEED Requirements

LEED projects in Canada continue to specify "Recycled content" requirements to promote sustainable design and low carbon concrete. Specification language such as "Concrete must replace a minimum 30% of Portland Cement by using post industrial recycled content (SCM in the cement)" is quite common and is considered prescriptive. Although this approach may have been beneficial in the past in achieving sustainable concrete, specifying minimum SCM values today can be quite detrimental to the overall project schedule and the flexibility with which ready mixed producers can operate. Furthermore, this is especially detrimental to achieving carbon reduction goals while considering special application requirements. The usage of performance-based specifications is highly encouraged and the shift from specifying prescriptive SCM values to instead defining performance GWP values is required. Since the project schedule and special applications will limit the ability to use SCMs as is showcased in the case study, using the prescriptive SCM specification approach is highly discouraged.

The usage of performance-based specifications is highly encouraged and the shift from specifying prescriptive SCM values to instead defining performance GWP values is required.

Aggregates

By volume, aggregates are the largest component of concrete and are inherently a low carbon product. Most aggregates are naturally occurring materials which require minimal processing and, are usually locally sourced The quality of aggregates used for concrete by ready mixed producers must be carefully considered as poor-quality materials can increase water demand or decrease strength and durability, resulting in a need to increase cement content which can have a detrimental impact on the GWP.

Aggregate Size

Aggregate size can have a significant impact on the cement content of a concrete and should be factored in when specifying aggregate size for a specific application. As a basic guideline, larger aggregate sizes generally require lower cement contents for the same or similar strength class compared to smaller aggregate sizes and therefore the carbon impact is also reduced, with the caution that constructability always needs to be considered.

Larger aggregate sizes are typically used for mass concrete applications such as foundations and help tremendously in lowering the heat of hydration. They are also very useful when designing concrete to meet low shrinkage requirements. The placement method must be considered as the increase in aggregate size may lead to depositing and consolidation issues and this aspect should be discussed with the contractor.

When decreasing the aggregate size whether it is for placement or pumpability aspects, the cement content is increased to compensate for the increase in surface area that must be covered by the paste and therefore an increase in the GWP values is observed.

Recycled Concrete Aggregate (RCA)

The usage of RCA in new concrete can have sustainable benefits as long as the composition of the RCA is consistent, and as specified in CSA A23.1, it does not impact the specified performance criteria of the concrete. Currently in most markets the primary application that typically uses RCA are road bases. Designers and specifiers will need to consult each individual ready mixed producer to determine whether suitable RCA sources are available and what replacement level can be used in new concrete.

Admixtures

Admixtures have become an essential component of modern concrete, and allow for unique and innovative building designs, improved jobsite placement, long-term durability, unique and new concrete behaviour parameters, and overall optimized, sustainable mix designs. Although the dosage rates of admixtures are minimal and their own carbon contribution is insignificant to a concrete mix design, their overall impact on the cement reduction and ultimate carbon impact of the concrete itself can be quite substantial. Water-reducing admixtures and superplasticizers can play a critical role in reducing the amount of water used and in turn lowering the water to cementitious materials ratio without the addition of extra cement. It is highly recommended that specifications do not sole-source the usage of a particular admixture and that they allow all CSA and ASTM compliant admixtures to help reduce the carbon impact of the concrete. Even with admixtures, a performance-based specification approach is critical for true lower carbon achievement.

It is highly recommended that specifications do not sole-source the usage of a particular admixture and that they allow all CSA and ASTM compliant admixtures to help reduce the carbon impact of the concrete. Even with admixtures, a performance-based specification approach is critical for true lower carbon achievement.

Early Strength Development Concrete

Building with ready mixed concrete offers designers and contractors flexibility in setting a realistic and attainable project schedule, as concrete can be placed at any time of the year. Furthermore, concrete mix designs can be optimized by the ready mixed concrete producer for scheduling needs as well as any required performance criteria and these changes can be made in real time as the project requirements and schedule changes.

However, sometimes the contractor can be required to place concrete during unfavourable cold-temperature conditions to meet the project schedule requirements. Since the strength development of in-situ concrete is highly dependent on temperature, and thus the time of year, it is critical that the designer and contractor understand the implications of placing concrete at different times of the year. If concrete placement is targeted for the spring and summer and a standard schedule is observed, the strength development timeline should be extended as long as possible to minimize the carbon impact as was previously discussed in the Performance-based Specifications section of this guide. On the other hand, if concrete will be required in the fall or winter, higher performance and accelerated mixes are often necessary, and the carbon reduction goals must be adjusted to accommodate the associated increase in GWP for those applications.

Compared to using conventional mixes in cold weather conditions, high early strength concrete reduces the length of time that temporary protection is required and offers savings from earlier reuse of forms and shores, shorter duration of temporary heating, earlier setting times for finishing flatwork, in addition to the earlier use of the structure. As with higher performance concretes, durability and strength parameters are often superior and the designer may be able to take advantage of the higher performance through smaller structural elements, reducing total concrete volume.

Cold Weather Concreting

As per CSA A23.1, Cold Weather Concreting is defined as providing protection "when there is a probability of the air temperature falling below 5°C within 24h of placing (as forecast by the nearest official meteorological office)." When these conditions occur, the ready mixed supplier is typically asked to provide mix designs that accelerate the set time and/or the strength gain of the concrete while still meeting the required performance criteria without any delays.

Cold weather has a substantial impact on the set time of concrete as temperature affects the rate at which hydration of the cement occurs. More specifically, low temperatures retard hydration and consequently slow down the hardening of the concrete. To compensate for this retardation and to achieve a similar performance of the concrete as would be observed on a 20°C day, the ready mixed producer has the following options:

1. Increasing the amount of Type GU or GUL used.
2. Reducing the amount of SCMs in the mix design, but not to the exclusion of durability performance specifications.
3. Incorporating set accelerating admixtures.

Accelerated Set Times

Typically, a combination of 2 to 3 of the options noted will be used by the ready mixed producer to balance the low ambient temperatures with an increased rate of setting and strength development. In addition to these options, protection and curing are vital to achieving increased set times in cold weather and must be executed properly by the contractor. In terms of sustainability, both options 1 and 2 will have a negative impact on the embodied carbon content of the concrete as has already been revealed by examining the provincial EPD reports.

Reducing the SCM percentage on mix designs has a similar impact as increasing the cement content shown above. Both increase the GWP and, overall, are necessary to achieve accelerated set times.

Accelerated Strength Gain

Similar to accelerated set times, an increased rate of strength development of a mix design can be achieved by increasing the cement content and by decreasing the SCM content. Alternatively, changing the cement type from Type GU or GUL to high early-strength (HE) cement will also achieve the same result. Typically, Type HE cement is a premium product and would not be available at all ready mixed facilities and therefore its availability must be planned for if it is required on a project. In addition, Type HE cement typically has a higher CO_2 /MT impact than its GU or GUL counterparts from the same source.

Overall, the increase in strength and/or the increase in rate of strength gain of mix designs will negatively impact the carbon reduction goals and therefore it must be planned at the start of the project so that the concrete carbon project budget can be balanced with standard mixes.

Carbon Mineralization Technology

Carbon mineralization or sequestration technology is currently available in the Canadian marketplace, and the technology injects a predetermined dosage of captured carbon dioxide into concrete during the mixing process where it ultimately mineralizes. In some cases, the process has been shown to improve the concrete's compressive strength, which allows for further mix optimization, leading to additional carbon footprint reductions and potentially even cost savings.

The specification of this technology is already being utilized by owners and architects to further reduce the carbon footprint of the concrete for Canadian projects. Since the usage of this technology is evolving and there are currently only a select few companies providing these services, it is important to fully understand how the carbon reductions will be achieved and what impact the technology will have on the EPD of the mix design. The specification of a singular company or product is highly discouraged, and a general technology approach should be taken when requirements are specified.

CONCRETE CARBON

CONCRETE CARBON PROJECT BUDGET (CCPB)

Setting GWP limits for specific concrete applications on a project allows the designer to clearly indicate performance requirements and ultimately control their carbon reduction goals. However, consider these challenges:

• The enforcement of these limits on a project, especially with cold weather concreting and project schedule impacts as were previously outlined, can become a significant constructability challenge.

• The consequences of not meeting these limits must also be clearly outlined, which is an aspect that the industry, including specifiers, have not been able to comprehensively define.

• Using application-specific GWP limits for carbon accounting on a project is unlikely to achieve effective carbon reduction goals.

• Specifying maximum GWP values for individual applications can create unanticipated problems on projects.

It is clear. A more flexible, mature, bigger picture approach is required.

A more sophisticated approach to carbon accounting on a concrete project is to use the concept of a **"Concrete Carbon Project Budget (CCPB)"**. This concept pre-determines a carbon budget by using anticipated concrete application volumes and the Global Warming Potentials (GWPs) of the Provincial Industry-Average EPD Baselines. The sum of these values then creates the CO2e Baseline for the project and once all the concrete has been placed, the CO2e Project value can be determined. Finally, a Green House Gas (GHG) reduction value for the entire project can be realized from the difference of those two project-level calculations and expressed as a percentage of the CO2e baseline.

The formulas presented define the variables, and an example is provided as well to showcase the concept of CCPB accounting.

$$\text{GHG reduction} = \text{CO2e Baseline} - \text{CO2e Project}$$

$$\%\ \text{GHG reduction} = \frac{(\text{GHG Reduction}) \cdot 100}{\text{CO2e Baseline}}$$

CO2e Baseline represents the emissions calculated by the anticipated volumes of all the mixes used on the project multiplied by the Global Warming Potentials (GWPs) of the Provincial Industry-Average EPD Baselines as represented by:

$$\text{CO2e Baseline} = \sum_{1}^{n} \text{Voln} \cdot \text{AveGWPn}$$

CO2e Project represents the emissions from the concrete placed on the project calculated by the volumes of all the mixes actually used on the project multiplied by their Global Warming Potential (GWPs) as represented by:

$$\text{CO2e Project} = \sum_{1}^{n} \text{Voln} \cdot \text{GWPn}$$

n = the total number of concrete mixes used on the project

Voln = the volume of mix n concrete to be placed (anticipated or actual)

GWPn = the global warming potential of mix n

AveGWPn = Global Warming Potentials (GWPs) of the Provincial Industry-Average EPD Baselines for the strength class of mix n

The following example, using the Ontario IA EPD, will explain how to use a CCPB for carbon accounting and the process to determine the project-level % GHG Reduction at the conclusion of the project.

1 Calculate Anticipated CO2e Baseline

To define an initial CO2e Baseline, the designer must determine the anticipated volumes for each mix design. This will outline a starting point for the CCPB.

Mix Design (n)	Anticipated Volume (m^3) (Voln)	Ontario Industry-Average EPD Baselines GWP (kg CO_2/m^3) (AveGWPn)	CO2e Baseline (tonnes CO_2)
25 MPa non-air	250	254.05	64
30 MPa non-air	100	264.38	26
35 MPa non-air	1500	295.46	443
30 MPa Class F-1	350	292.72	102
35 MPa Class C-1	75	313.07	23
Total	**2275**	**Total CO2e Baseline**	**659**

Using this example, the anticipated CO2e Baseline for this project would be 659 tonnes of CO_2. Since the volumes are anticipated, they will need to be continuously adjusted as the project progresses until the actual volumes of the project are achieved. This means that the CCPB will fluctuate to accurately represent the actual volumes required.

To reflect actual volumes at the project completion level, the following table will be used for this example.

2 Adjust & Calculate Final CO2e Baseline

Mix Design (n)	Actual Volume (m^3) (Voln)	Ontario Industry-average EPD Baselines GWP (kg CO_2/m^3) (AveGWPn)	CO2e Baseline (tonnes CO_2)
25 MPa non-air	253	254.05	64
30 MPa non-air	125	264.38	33
35 MPa non-air	1600	295.46	473
30 MPa Class F-1	310	292.72	91
35 MPa Class C-1	75	313.07	23
Total	**2363**	**Total CO2e Baseline**	**684**

With the adjusted volumes at project completion, the final CO2e Baseline value becomes 684 tonnes of CO_2.

3 Calculate CO2e Project

• GWP reduction • GWP increase

Mix Design (n)	Actual Volume (m^3) (Voln)	Ontario Industry-average EPD GWP (kg CO_2/m^3) (GWPn)	CO2e Project (tonnes CO_2)
25 MPa non-air	253	224.62	57
30 MPa non-air	125	242.88	30
35 MPa non-air	1600	210.18	336
30 MPa Class F-1	310	329.02	102
35 MPa Class C-1	75	284.38	21
Total	**2363**	**Total CO2e Project**	**547**

Note: Not all of the mixes used on the project were below their individual baseline values. This reflects instances where special applications, accelerated construction requirements, or cold weather placement were used.

In this example, using the actual volumes and the Ontario Industry-Average EPD information of the mixes that were actually placed, an overall CO2e Project emission of 547 tonnes of CO_2 is calculated for this hypothetical project. Industry-average information of mix designs is the standard starting point for any concrete carbon calculations. If more accurate information is needed, Type II or even Type III EPD information from ready mixed producers can also be used here for more accurate carbon reduction savings.

4 Calculate GHG Reduction

Having calculated the CO2e Baseline (684 tonnes CO_2) and CO2e Project (547 tonnes CO_2) values, the GHG Reduction in tonnes of CO_2 for this project is 684-547 = 137.

5 Calculate % GHG Reduction

Finally, using the values calculated previously, the % GHG Reduction for the overall project is (137*100)/684 = 20%.

Overall, this very simple project example would have achieved a 20% CO_2 reduction over the Ontario Industry-Average EPD Baselines. Factors such as an accelerated project schedule or specialty applications were not accounted for and will be covered in the case study.

Special Application Carbon Impact

The importance of special applications, such as SCC, shotcrete, and accelerated mix designs, and their associated impact on carbon reduction goals have been clearly outlined in this guideline.

These specialty concretes are critical in achieving architectural concrete and in allowing the contractor to maintain a reasonable project schedule and therefore the usage of these mixes must be factored into the CCPB. To address this aspect, an increase in the GWP of the Provincial Industry-Average Baseline EPDs is a necessary solution and this increase has already been well established by the Government Services Administration (GSA) in the United States and has been included in the standard (recently) set by the Treasury Board of Canada Secretariat for major federal projects. Both agencies represent significant infrastructure projects and the inclusion of an increased GWP value for special applications establishes a key addition to the process of the CCPB.

Government Services Administration (GSA)

Increasing the GWP of baselines to accommodate special applications is a strategy which has already been implemented as part of the Biden-Harris Administration "Buy Clean" Task Force in the United States through the Government Services Administration (GSA). The GSA oversees $75 billion in annual contracts for the federal government and announced in March 2022 that it will set a new standard for contractors to use low embodied carbon concrete in all its major construction projects.

This announcement included a specification titled **"The Low Embodied Carbon Concrete Standards for all GSA Projects specification"** and it outlines a 35% increase of GWP from Standard to High Early Strength mixes and even a greater increase for Lightweight mixes. With the release of this specification, the missing component of how to deal with concrete special applications and their impact on carbon budget has been solved and it paved the way for the Treasury Board of Canada Secretariat to also incorporate this aspect as part of their upcoming specifications.

GSA

Download PDF Document

Treasury Board of Canada Secretariat

Led by the Centre for Greening Government of the Treasury Board of Canada Secretariat, the Government of Canada is looking to establish Canada as a global leader in government operations that are net-zero, resilient and green. Through this strategy the government will reduce the environmental impact of structural construction materials on all new federal projects by:

- Disclosing the amount of embodied carbon in the structural materials of major construction projects by 2022, based on material carbon intensity or a life-cycle analysis
- Reducing the embodied carbon of the structural materials of major construction projects by 30%, starting in 2025, using recycled and lower-carbon materials, material efficiency and performance-based design standards
- Conducting whole building (or asset life-cycle assessments by 2025 at the latest for major buildings and infrastructure projects

For the full details of the strategy, please visit:
https://www.canada.ca/en/treasury-board-secretariat/services/innovation/greening-government/strategy.html

Similar to the GSA, the Treasury Board recently released their **Standard on Embodied Carbon in Construction**, which outlines the concept of the CCPB as shown in this guideline and it addresses the special application issue. The Treasury Board, in discussions with Concrete Ontario and the Cement Association of Canada, is standardizing the following: The baseline (AveGWP in the example) used for Special Application Requirements shall be 130% of the Regional (Provincial) Industry-Average Baseline EPDs for that strength class.

Treasury Board of Canada Secretariat

Standard on Embodied Carbon in Construction:

https://www.tbs-sct.canada.ca/pol/doc-eng.aspx?id=32742

The baseline (AveGWP in the example) used for Special Application Requirements shall be 130% of the Regional (Provincial) Industry-Average Baseline EPDs for that strength class.

We believe this requirement should apply for the following special application mixes:

1. **High early strength**
2. **High-performance**

High-performance concrete is defined as per CSA A23.1:

High-performance concrete (HPC) — concrete that meets performance requirements that cannot always be achieved routinely by using only conventional materials and normal mixing, placing, and curing practices.

3. **Cold-weather application**

As per CSA A23.1:

7.2.2 Cold weather concreting

Protection shall be provided when there is a probability of the air temperature falling below 5°C within 24 h of placing (as forecast by the nearest official meteorological office).

Using this information, an additional component can be used in the CCPB GWP targets, as shown in the following example.

2B Adjust & Calculate Anticipated CO2e Baseline for ANY Special Application Mixes

Mix Design (n)	Ontario Industry-average EPD Baselines GWP (kg CO_2/m^3) (AveGWPn)	Ontario Industry-average EPD Baselines GWP (kg CO_2/m^3) (AveGWPn) Special Application
25 MPa non-air	254.05	254.05 x 1.3 = 330.27
30 MPa non-air	264.38	264.38 x 1.3 = 343.69
35 MPa non-air	295.46	295.46 x 1.3 = 384.10
30 MPa Class F-1	292.72	292.72 x 1.3 = 380.54
35 MPa Class C-1	313.07	313.07 x 1.3 = 406.99

Having the ability to accommodate special application mix requirements, which the contractor might need to execute the project effectively, is essential to creating a balanced project schedule and carbon reduction goals. This 30% increase in GWP baselines is a good starting point which can always be adjusted as the industry continues to gather more experience regarding low carbon concrete goals and objectives.

Carbon Reduction Goals

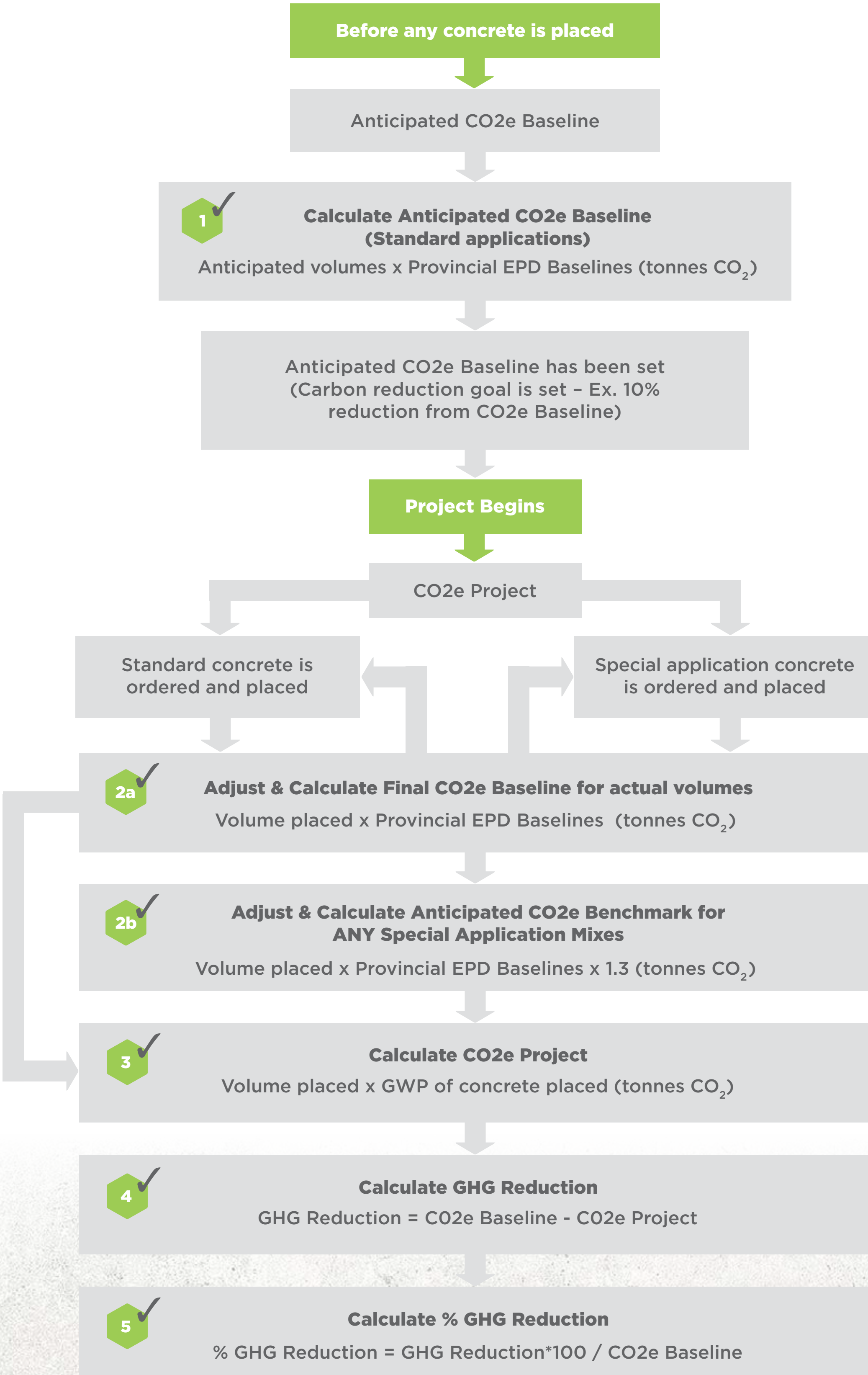
While both owner and specifier have the liberty to choose their own carbon reduction target based on the structure that is being built, setting a consistent target will allow the industry to gauge how achievable these targets are based on the EPD report. As more and more projects are completed, the validity of the carbon reduction goals will be confirmed, and consistent targets can then be evaluated for future projects.

Through 2022 and ongoing, CRCMA and the Cement Association of Canada have been in discussions with the Treasury Board of Canada Secretariat, and the following approach has been established as the starting point for concrete carbon reductions for all future Government of Canada projects:

The total project GHG emissions from ready-mix concrete shall be at least 10% less than those calculated using the GWPs of the baseline mix in the Regional (Provincial) Industry Average Environmental Product Declaration (EPD) for the strength class of each mix and the volume of mix placed. (i.e., % GHG Reduction calculation of minimum 10%)

This requirement is part of the already mentioned **Standard on Embodied Carbon in Construction** specification.

Using the example provided previously, a reduction of 20% was achieved for the hypothetical project and this means that the industry-proposed and Government-of-Canada-standardized carbon reduction goal of at least 10% would have been met. Defining a realistic and attainable carbon reduction goal from the start sets the expectation for the project to ensure that all stakeholders are aligned.


Before any concrete is placed
Anticipated CO2e Baseline
1
Calculate Anticipated CO2e Baseline (Standard applications)
Anticipated volumes x Provincial EPD Baselines (tonnes CO_2)
Anticipated CO2e Baseline has been set (Carbon reduction goal is set – Ex. 10% reduction from CO2e Baseline)
Project Begins
CO2e Project
Standard concrete is ordered and placed
Special application concrete is ordered and placed
2a
Adjust & Calculate Final CO2e Baseline for actual volumes
Volume placed x Provincial EPD Baselines (tonnes CO_2)
2b
Adjust & Calculate Anticipated CO2e Benchmark for ANY Special Application Mixes
Volume placed x Provincial EPD Baselines x 1.3 (tonnes CO_2)
3
Calculate CO2e Project
Volume placed x GWP of concrete placed (tonnes CO_2)
4
Calculate GHG Reduction
GHG Reduction = C02e Baseline - C02e Project
5
Calculate % GHG Reduction
% GHG Reduction = GHG Reduction*100 / CO2e Baseline

ONTARIO
CASE STUDY

THE MET CONDOMINIUMS

CONCRETE ONTARIO

DEVELOPER: PLAZA/BERKLEY DEVELOPMENTS

ONTARIO CASE STUDY

A condominium project has been chosen as an effective case study to demonstrate the importance of balancing carbon reduction goals with the project schedule. Condo projects continue to increase mix design requirements as the project evolves which may have negative impacts on the embodied carbon of the concrete. To fully see the repercussions of having accelerated mix designs due to cold weather and project schedule requirements, this case study will showcase a step-by-step process of how to determine a CCPB and the results associated with using special application mix designs.

The Met and projected future development in Downtown Vaughan, image courtesy of Plaza/Berkeley

The Met Condominiums

"The Met" is a 35-storey condominium tower on Jane Street, north of Highway 7, in Vaughan and was developed by Plaza and Berkley Developments. It features 3 levels of underground parking and preliminary site preparation work started in December 2016. Since this project was completed between 2016 and 2019, it is very important to note that carbon reduction goals were not yet a primary focus of designers and specifiers, and, as such, the mix designs were not optimized to ensure that low carbon concrete was achieved. The case study's primary purpose is to showcase how a typical project schedule and special application mix designs, such as cold weather concreting can impact concrete carbon budgets. Using the information provided in this guideline and already available concrete carbon resources such as EPDs, designers and specifiers can formulate a plan to achieve their carbon reduction goals today.

The Met, Berkley, Quadrangle Architects, Plaza, Vaughan

Concrete Needs on The Met

As part of the mix design submittal and review process, approximately 20 mix designs were submitted by the ready mixed producer to the contractor over the course of the project. However, once the project schedule and cold weather concreting requirements were fully implemented by the contractor, approximately 140 different mix design variations were used upon project completion. Mix design variations included a variety of performance enhancements such as:

1. **Accelerated set and strengths**
2. **Enhancement of slumps**
3. **Aggregate size adjustments**
4. **Fiber usage**
5. **Specialty admixtures (e.g., Corrosion inhibitors and retarders)**

This increase in specialized mix designs had a significant impact on the overall embodied carbon of the concrete, which will be discussed throughout the case study. It should be noted that the increase in the number of mix design numbers is typical for a project such as this, and it is attributable to the flexibility that concrete offers to accommodate the schedule, the structural requirements and the ease of placement under a variety of conditions.

The following summary of mix designs and associated applications represents the majority of the concrete placed for this project. Low strength fills were excluded from the calculations. The cement type for all concrete was either Type GU or Type GUbSF since Type GUL was not yet readily available.

Mix Design	Applications
15 MPa without air	N/A
25 MPa without air	Interior slabs
25 MPa Class C-4	Slab on grade
30 MPa without air	Footings, slabs, columns & walls (21st floor – roof)
30 MPa Class F-1	Balconies, terraces, mechanical PH roof
35 MPa without air	Slabs & beams, columns & walls (14th floor – u/s 21st floor)
35 MPa Class F-2	Perimeter foundation walls, columns & walls (14th floor – u/s 21st floor)
35 MPa Class C-1	Parking slabs, balconies & terraces
40 MPa without air	Columns & walls (7th floor – u/s 14th floor)
45 MPa without air	Beams, pick-up slabs, columns & walls (2nd floor – u/s 7th floor)
45 MPa Class F-2	Columns & walls (2nd floor – u/s 7th floor)
45 MPa Class C-1	N/A
50 MPa without air	Columns & walls
50 MPa Class F-2	Columns & walls
60 MPa Class F-2	N/A

Knowing the concrete mix designs that are required for the project, the process of determining the CCPB can begin. The same procedure which was used in the “Example” will be followed for this case study.

STEP 1: CALCULATE ANTICIPATED CO2e BASELINE

This represents a table of the anticipated mix designs and volumes for the project, and the tonnes of CO_2 using the baseline GWP numbers.

Mix Design	Anticipated Volume (m^3)	Application	Ontario Industry-Average EPD Baseline Mix	Baseline GWP (kg CO_2/m^3)	CO2e Baseline (tonnes CO_2)
15 MPa without air	600	Standard	**Baseline 20 MPa concrete without air GU 10 SL	220.29	132.2
25 MPa without air	7,000	Standard	Baseline 25 MPa concrete without air GU 10 SL	254.05	1,778.4
25 MPa Class C-4	900	Standard	**Baseline 25 MPa concrete with air & 0.55 w/cm (F-2) GU 10 SL	260.64	234.6
30 MPa without air	2,500	Standard	Baseline 30 MPa concrete without air GU 15 SL	264.38	660.9
30 MPa Class F-1	3,500	Standard	Baseline 30 MPa concrete with air & 0.50 w/cm (F-1) GU 15 SL	292.72	1,024.5
35 MPa without air	2,500	Standard	Baseline 35 MPa concrete without air GU 15 SL	295.46	738.7
35 MPa Class F-2	1,500	Standard	Baseline 35 MPa concrete with air GU 15 SL	334.49	501.7
35 MPa Class C-1	5,250	Standard	Baseline 35 MPa concrete with air & 0.40 w/cm (C-1) GU 25 SL	313.07	1,643.6
40 MPa without air	1,000	Standard	Baseline 40 MPa concrete without air GU 15 SL	326.25	326.3
45 MPa without air	3,000	Standard	Baseline 45 MPa concrete without air GU 15 SL	349.88	1,049.7
45 MPa Class F-2	20	Standard	Baseline 45 MPa concrete with air GU 15 SL	379.45	7.6
45 MPa Class C-1	1,700	Standard	**45 MPa concrete with air GU 25 SL	347.24	590.3
50 MPa without air	70	Standard	Baseline 50 MPa concrete without air GUbSF 20 SL	335.76	23.5
50 MPa Class F-2	1,100	Standard	Baseline 50 MPa concrete with air GUbSF 20 SL	456.93	502.6
60 MPa Class F-2	150	Standard	**50 MPa concrete with air GUbSF	535.65	80.3
Total:	**30,790**			**Total:**	**9,294.9**

Photos: Edward Skira

Photo: DarksideDenizen

Due to the limited number of Ontario baselines available, the designer will have to determine which baselines to use if the required mix design is not available.

**For this case study, the following interpretations were made:

1. 15 MPa baseline is not available and thus the 20 MPa has been selected
2. Class C-4 concrete has the same performance criteria as Class F-2 and thus the Class F-2 baseline can be selected
3. 45 MPa Class C-1: Class C-1 mix designs require a minimum of 25% SL as previously outlined in this guideline, and thus the 45 MPa concrete with air GU 25 SL baseline was selected
4. 60 MPa baseline is not available and thus the most stringent 50 MPa concrete with air GUbSF version was selected

At this stage, the designer has estimated the volumes for each mix design and applied the Ontario Industry-Average EPD Baselines to determine the total CO2e Baseline (Volume x Baseline GWP). The mix designs are assumed to be standard applications, and the designs for special applications, such as accelerated set and strength, are unknown. The designs for special applications will be developed as the contractor communicates the concrete placement and project schedule requirements to the ready mixed producer, at which point the CO2e Baseline will need to be adjusted.

The Met, Berkley, Quadrangle Architects, Plaza, Vaughan

The Final CO2e Baseline requires the actual volumes of concrete placed and must factor in the special application component, which has a significant impact. Special applications such as architectural concrete, accelerated set and strength, and cold weather concreting will all impact the CCPB and must be accounted for to address constructability challenges that exist on numerous projects. For the Met, the following is a comprehensive breakdown of the numerous mix designs that were used.

STEP 2: ADJUST & CALCULATE FINAL CO2e BASELINE

This table represents an update to the table in Step 1, updated as the project progresses, capturing additional mix designs and specialty applications, and actual volumes, to represent the final baseline for the project.

Mix Design	Application	Total Volume (m^3)	Ontario Industry-Average EPD Baseline Mix	Baseline GWP (kg CO_2/m^3)	Updated Baseline GWP (kg CO_2/m^3) (30% increase)	C02e Baseline (tonnes CO_2)
15 MPa without air	Standard	626.0	Baseline 20 MPa concrete without air GU 10 SL	220.29	N/A	137.9
25 MPa without air	Standard	2,596.2	Baseline 25 MPa concrete without air GU 10 SL	254.05	N/A	659.6
25 MPa Class C-4	Standard	548.0	Baseline 25 MPa concrete with air & 0.55 w/cm (F-2) GU 10 SL	260.64	N/A	142.8
30 MPa without air	Standard	943.0	Baseline 30 MPa concrete without air GU 15 SL	264.38	N/A	249.3
30 MPa Class F-1	Standard	1,090.6	Baseline 30 MPa concrete with air & 0.50 w/cm (F-1) GU 15 SL	292.72	N/A	319.2
35 MPa without air	Standard	2,031.0	Baseline 35 MPa concrete without air GU 15 SL	295.46	N/A	600.1
35 MPa Class F-2	Standard	1,184.8	Baseline 35 MPa concrete with air GU 15 SL	334.49	N/A	396.3
35 MPa Class C-1	Standard	2,245.8	Baseline 35 MPa concrete with air & 0.40 w/cm (C-1) GU 25 SL	313.07	N/A	703.1
40 MPa without air	Standard	1,123.0	Baseline 40 MPa concrete without air GU 15 SL	326.25	N/A	366.4
45 MPa without air	Standard	1,827.4	Baseline 45 MPa concrete without air GU 15 SL	349.88	N/A	639.4
45 MPa Class F-2	Standard	9.0	Baseline 45 MPa concrete with air GU 15 SL	379.45	N/A	3.4
45 MPa Class C-1	Standard	909.6	45 MPa concrete with air GU 25 SL	347.24	N/A	315.9
50 MPa without air	Standard	68.6	Baseline 50 MPa concrete without air GUbSF 20 SL	335.76	N/A	23.0
50 MPa Class F-2	Standard	411.0	Baseline 50 MPa concrete with air GUbSF 20 SL	456.93	N/A	187.8
60 MPa Class F-2	Standard	132.0	50 MPa concrete with air GUbSF	535.65	N/A	70.7
25 MPa without air	Special	408.4	Baseline 25 MPa concrete without air GU 10 SL	254.05	330.27	134.9
25 MPa Class C-4	Special	457.4	Baseline 25 MPa concrete with air & 0.55 w/cm (F-2) GU 10 SL	260.64	338.83	155.0
30 MPa without air	Special	1,421.6	Baseline 30 MPa concrete without air GU 15 SL	264.38	343.69	488.6
30 MPa Class F-1	Special	809.8	Baseline 30 MPa concrete with air & 0.50 w/cm (F-1) GU 15 SL	292.72	380.53	308.2

Continued on Page 52

STEP 2: ADJUST & CALCULATE FINAL CO2e BASELINE CONTINUED

Mix Design	Application	Total Volume (m³)	Ontario Industry-Average EPD Baseline Mix	Baseline GWP (kg CO_2/m³)	Updated Baseline GWP (kg CO_2/m³) (30% increase)	CO2e Baseline (tonnes CO_2)
35 MPa without air	Special	147.6	Baseline 35 MPa concrete without air GU 15 SL	295.46	384.10	56.7
35 MPa Class F-2	Special	362.0	Baseline 35 MPa concrete with air GU 15 SL	334.49	434.84	157.4
35 MPa Class C-1	Special	2,018.6	Baseline 35 MPa concrete with air & 0.40 w/cm (C-1) GU 25 SL	313.07	406.99	821.6
45 MPa without air	Special	592.6	Baseline 45 MPa concrete without air GU 15 SL	349.88	454.85	269.5
45 MPa Class C-1	Special	736.0	45 MPa concrete with air GU 25 SL	347.24	451.42	332.2
50 MPa Class F-2	Special	690.0	Baseline 50 MPa concrete with air GUbSF 20 SL	456.93	594.01	409.9
25 MPa without air (75% @ 24H)	Special	36.0	Baseline 25 MPa concrete without air GU 10 SL	254.05	330.27	11.9
25 MPa without air (75% @ 48H)	Special	4,064.8	Baseline 25 MPa concrete without air GU 10 SL	254.05	330.27	1,342.5
30 MPa without air (75% @ 48H)	Special	13.0	Baseline 30 MPa concrete without air GU 15 SL	264.38	343.69	4.5
30 MPa Class F-1 (75% @ 24H)	Special	69.6	Baseline 30 MPa concrete with air & 0.50 w/cm (F-1) GU 15 SL	292.72	380.53	26.5
30 MPa Class F-1 (75% @ 48H)	Special	1,585.4	Baseline 30 MPa concrete with air & 0.50 w/cm (F-1) GU 15 SL	292.72	380.53	603.3
35 MPa without air (75% @ 48H)	Special	333.0	Baseline 35 MPa concrete without air GU 15 SL	295.46	384.10	127.9
35 MPa Class C-1 (75% @ 48H)	Special	1,048.2	Baseline 35 MPa concrete with air & 0.40 w/cm (C-1) GU 25 SL	313.07	406.99	426.6
45 MPa without air (75% @ 48H)	Special	302.2	Baseline 45 MPa concrete without air GU 15 SL	349.88	454.85	137.5
45 MPa Class C-1 (75% @ 48H)	Special	72.0	45 MPa concrete with air GU 25 SL	347.24	451.42	32.5
	Total:	30,914.2			Total:	10,661.9

STEP 2B: ADJUST & CALCULATE ANTICIPATED CO2e BASELINE FOR ANY SPECIAL APPLICATION MIXES

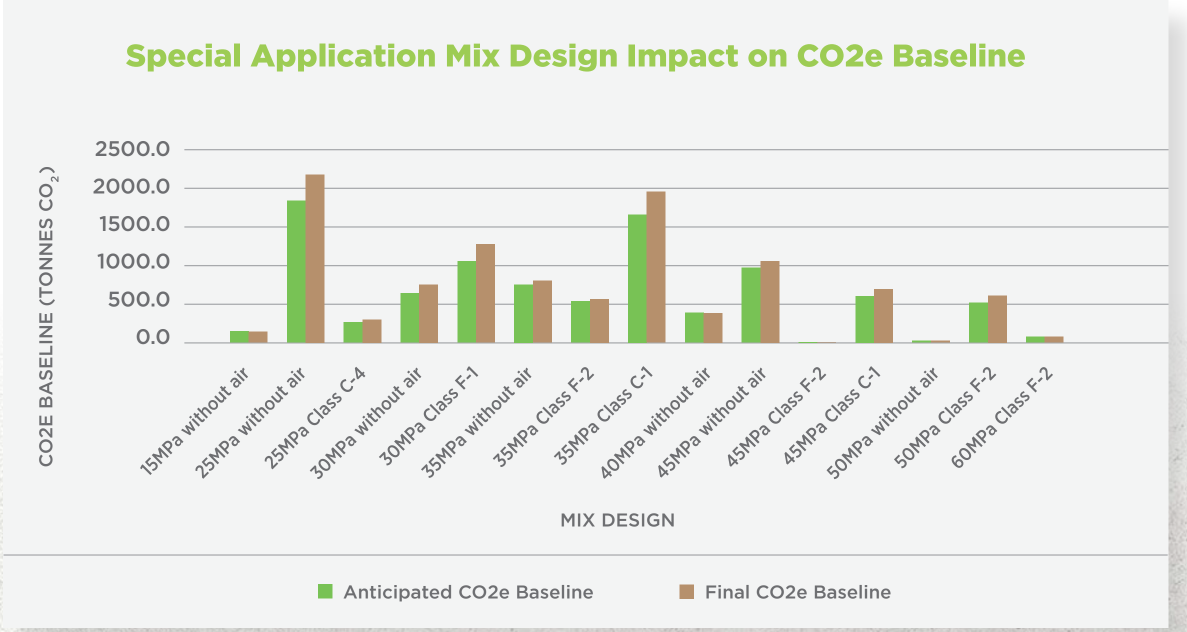
As portions of the project needed to meet accelerated strength requirements to stay within the project schedule, the CO2e Baseline consequently increased from 9,294.9 to 10,661.9 tonnes CO_2, a 14.7% increase. The Final CO2e Baseline calculation can only be completed once all the concrete has been placed but it also needs to be tracked as the project progresses to ensure that carbon reduction goals will be achieved.

If 20 m³ of 45 MPa Class C-1 (75% @ 48H) will be placed, the updated CO2e Baseline after the placement would be increased as follows:

$$20\ m^3 \times 451.42\ kg\ CO_2/m^3 = 9.0\ tonnes\ CO_2$$

This 9.0 tonnes CO_2 would be factored into the budget at that time during the project and, would represent 27.7% of the overall carbon budget of that mix at the end of the project. (Total CO2e Baseline of mix = 32.5 tonnes CO_2) The other application CO2e Baselines remain the same until a special application is required.

The transition from the Anticipated CO2e Baseline to the Final CO2e Baseline will need to be carefully managed by a sustainability expert to keep the project on track with the intended carbon reduction goals. As the project progresses, the carbon reduction goals should be evaluated to determine where optimization in terms of concrete mix designs can be achieved. A visualization of how the CO2e Baseline changed for the Met project is presented. Final concrete volume values were used in each case.



STEP 3: CO2e PROJECT CALCULATION

This table represents the actual volumes and actual GWP values to compare against the final baseline from Step 2.

Mix Design	Application	Total Volume (m^3)	Ontario Industry-Average EPD Mix	Ontario Industry-Average EPD GWP (kg CO_2)	CO2e Project (tonnes CO_2)
15 MPa without air	Standard	626.0	20 MPa concrete without air GU 15 SL	211.99	132.7
25 MPa without air	Standard	2,596.2	25 MPa concrete without air GU 15 SL	244.24	634.1
25 MPa Class C-4	Standard	548.0	25 MPa concrete with air & 0.55 w/cm (F-2) GU 25 SL	230.26	126.2
30 MPa without air	Standard	943.0	30 MPa concrete without air GU 15 SL	264.38	249.3
30 MPa Class F-1	Standard	1,090.6	30 MPa concrete with air & 0.50 w/cm (F-1) GU 15 SL	292.72	319.2
35 MPa without air	Standard	2,031.0	35 MPa concrete without air GU 30 SL	258.92	525.9
35 MPa Class F-2	Standard	1,184.8	35 MPa concrete with air GU 25 SL	306.42	363.0
35 MPa Class C-1	Standard	2,245.8	35 MPa concrete with air & 0.40 w/cm (C-1) GU 35 SL	284.38	638.7
40 MPa without air	Standard	1,123.0	40 MPa concrete without air GU 30 SL	285.48	320.6
45 MPa without air	Standard	1,827.4	45 MPa concrete without air GU 30 SL	305.72	558.7
45 MPa Class F-2	Standard	9.0	45 MPa concrete with air GU 25 SL	347.24	3.1
45 MPa Class C-1	Standard	909.6	45 MPa concrete with air GU 25 SL	347.24	315.9
50 MPa without air	Standard	68.6	50 MPa concrete without air GUbSF 25 SL	321.41	22.0
50 MPa Class F-2	Standard	411.0	50 MPa concrete with air GUbSF 25 SL	437.25	179.7
60 MPa Class F-2	Standard	132.0	50 MPa concrete with air GUbSF 25 SL	437.25	57.7
25 MPa without air	Special	408.4	Baseline 25 MPa concrete without air GU 10 SL	254.05	103.8
25 MPa Class C-4	Special	457.4	Baseline 25 MPa concrete with air & 0.55 w/cm (F-2) GU 10 SL	260.64	119.2
30 MPa without air	Special	1,421.6	Baseline 30MPa concrete without air GU 15 SL	264.38	375.8
30 MPa Class F-1	Special	809.8	30 MPa concrete with air & 0.50 w/cm (F-1) GU 15 SL	292.72	237.0
35 MPa without air	Special	147.6	35 MPa concrete without air GU 15 SL	295.46	43.6
35 MPa Class F-2	Special	362.0	Baseline 35 MPa concrete with air GU 15 SL	334.49	121.1
35 MPa Class C-1	Special	2,018.6	35 MPa concrete with air & 0.40 w/cm (C-1) GU 25 SL	313.07	632.0
45 MPa without air	Special	592.6	Baseline 45 MPa concrete with air GU 15 SL	379.45	224.9
45 MPa Class C-1	Special	736.0	45 MPa concrete with air GU 25 SL	347.24	255.6
50 MPa Class F-2	Special	690.0	50 MPa concrete with air GUbSF 15 SL	476.61	328.9
25 MPa without air (75% @ 24H)	Special	36.0	40 MPa concrete without air GU 15 SL	326.25	11.7
25 MPa without air (75% @ 48H)	Special	4,064.8	35 MPa concrete without air GU 15 SL	295.46	1,201.0
30 MPa without air (75% @ 48H)	Special	13.0	45 MPa concrete without air GU 15 SL	349.88	4.5
30 MPa Class F-1 (75% @ 24H)	Special	69.6	45 MPa concrete with air GU 15 SL	379.45	26.4
30 MPa Class F-1 (75% @ 48H)	Special	1,585.4	40 MPa concrete with air GU 15 SL	361.65	573.4
35 MPa without air (75% @ 48H)	Special	333.0	60 MPa concrete without air GUbSF 15 SL	376.81	125.5
35 MPa Class C-1 (75% @ 48H)	Special	1,048.2	50 MPa concrete with air GUbSF 25 SL	437.25	458.3
45 MPa without air (75% @ 48H)	Special	302.2	70 MPa concrete without air GUbSF 15 SL	386.50	116.8
45 MPa Class C-1 (75% @ 48H)	Special	72.0	50 MPa concrete with air GUbSF 15 SL	476.61	34.3
	Total:	**30,914.2**		**Total:**	**9,440.6**

Ontario Industry-Average EPD Mixes which were extrapolated to produce additional SL percentages and comparable accelerated mix designs which are not available. Selections were made based on the review of cement contents and compared to the Industry-Average submitted values.

At the project close out stage, the CCPB can be analyzed to determine how the mix designs that were used impacted the overall carbon reduction goals. Using the available Ontario Industry-Average EPD mixes, the CO2e Project can be calculated for the Met which ended up being 9,440.6 tonnes of CO_2 as shown in the Step 3 table. The challenge with using available Industry-Average EPD mixes is that not all variations that were used in the field will be available to help the sustainability expert to determine an accurate representation of the CO2e Project. As such, guidance from the ready mixed producer in determining which Industry-Average mixes most closely correspond to the actual mix designs is necessary. A more effective method of GWP quantification is using Type II and Type III EPDs as they more accurately reflect the mix designs and can provide a more effective means of carbon accounting and reduction. A collaborative effort between the designer, contractor, and ready mixed producer is therefore required to achieve consistent and accurate carbon accounting.

A more effective method of GWP quantification is using Type II and Type III EPDs as they more accurately reflect the mix designs and can provide a more effective means of carbon accounting and reduction.

The Met, Berkley, Quadrangle Architects, Plaza, Vaughan

STEP 4: CALCULATE GHG REDUCTION

Having calculated the Final CO2e Baseline (10,661.9 tonnes CO_2) and CO2e Project (9,440.6 tonnes CO_2) values, the GHG Reduction in tonnes of CO_2 for this project is

$$10{,}661.9 - 9{,}440.6 = 1{,}221.3$$

STEP 5: CALCULATE % GHG REDUCTION

Finally, using the values calculated, the % GHG Reduction for the overall project is

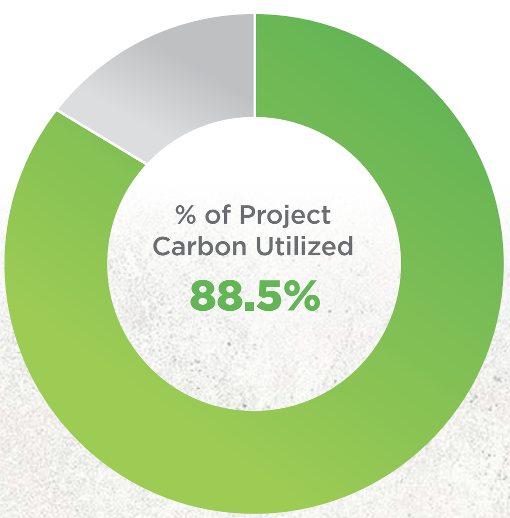
$$(1{,}221.3 * 100)/10{,}661.9 = 11.5\%$$

Project Summary

Applying the concept of the CCPB and following the process throughout the case study, the Met project would have achieved a 11.5% reduction in CO_2. A full summary of the Final CO2e Baseline versus the CO2e Project results are shown here.

This reduction is quite significant, especially considering that the carbon reduction goals and project schedule were not optimized to achieve low carbon concrete. If this project was to be designed and specified today, with carbon reduction goals outlined from the start and enforced throughout the project, a much greater reduction in CO_2 would likely be achieved. In addition, the availability of Type GUL cement would lead to a much larger carbon reduction.

Concrete Carbon Project Summary (Type GU)



Summary

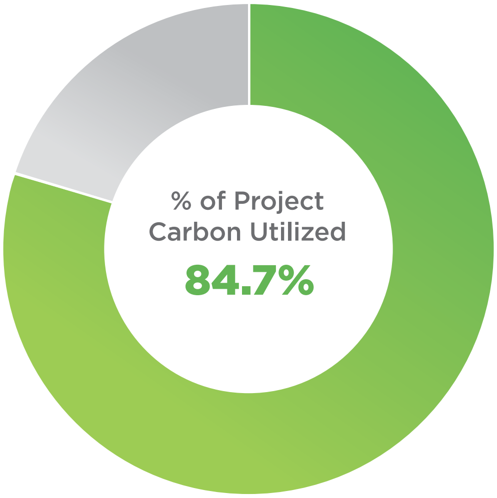
Total Concrete Carbon Project Budget
10,661.9 tonnes CO_2

Total Carbon Project Impact
9,440.6 tonnes CO_2

Total Carbon Savings
1,221.3 tonnes CO_2

% GHG Reduction
11.5%

Concrete Carbon Project Summary (Type GUL)



Summary

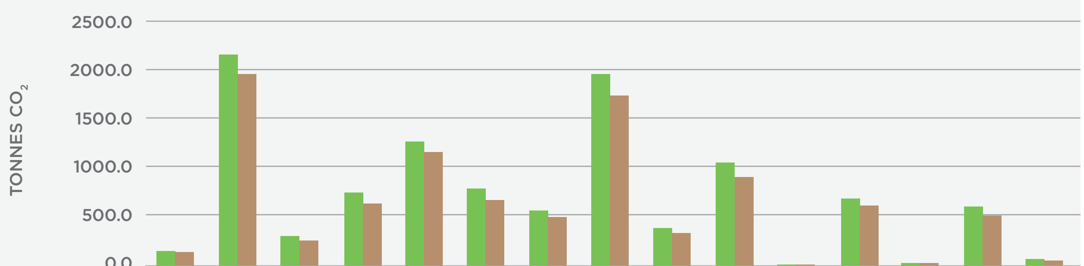
Total Concrete Carbon Project Budget
10,661.9 tonnes CO_2

Total Carbon Project Impact
9,032.4 tonnes CO_2

Total Carbon Savings
1,629.5 tonnes CO_2

% GHG Reduction
15.3%

Final CO2e Baseline vs Project CO2e Results



	15 MPa without air	25 MPa without air	25 MPa Class C-4	30 MPa without air	30 MPa Class F-1	35 MPa without air	35 MPa Class F-2	35 MPa Class C-1	40 MPa without air	45 MPa without air	45 MPa Class F-2	45 MPa Class C-1	50 MPa without air	50 MPa Class F-2	60 MPa Class F-2
Final CO2e Baseline	137.9	2148.8	297.8	742.4	1257.2	784.7	553.7	1951.3	366.4	1046.4	3.4	680.6	23.0	597.7	70.7
CO2e Project	132.7	1950.6	245.4	629.7	1156.1	663.5	484.1	1729.0	320.6	900.3	3.1	605.7	22.0	508.6	57.7

MIX DESIGN

Final CO2e Baseline   CO2e Project

Specifier Considerations

The concept of the CCPB clearly demonstrates the importance of not relying on application specific GWP values for carbon accounting as on numerous instances, as mix designs may need to be adjusted for a variety of valid reasons and will exceed the specified GWP values once special applications are considered. For the Met project, in numerous cases the standard mix design baselines were exceeded due to special application mix design requirements and the consequences of hard specifying any GWP value would have had to be addressed by the consultant, the contractor and ready mixed producer.

The 30 MPa Class F-1 mix designs (Balconies, terraces, mechanical PH roof) are a perfect example of how the standard GWP values were exceeded and a summary is provided. Special application GWP baselines are also indicated to highlight their importance.

30 MPa CLASS F-1 USAGE

Mix Design	Application	Total Volume (m^3)	% of Total Mix Volume	Baseline GWP (kg CO_2/m^3)	Updated Baseline GWP (kg CO_2/m^3) (30% increase)	CO2e Baseline (tonnes CO_2)	Ontario Industry-Average EPD GWP (kg CO_2/m^3)	Standard Baseline versus Ontario Industry-Average EPD GWP	CO2e Project (tonnes CO_2)	Final Mix % GHG Reduction w/ Updated Baseline (30% increase)
30MPa Class F-1	Standard	1,090.6	31%	292.72	N/A	319.2	292.72	0.0%	319.24	0.0%
30MPa Class F-1	Special	809.8	23%	292.72	380.53	308.2	292.72	0.0%	237.04	23.1%
30MPa Class F-1 (75% @ 24H)	Special	69.6	2%	292.72	380.53	26.5	379.45	29.6%	26.41	0.3%
30MPa Class F-1 (75% @ 48H)	Special	1,585.4	45%	292.72	380.53	603.3	361.65	23.5%	573.36	5.0%
Total:		**3,555.4**								

In summary, had the standard baseline GWP value been specified exclusively for this application for all 3,555.4 m^3, 47% of the volume that was placed would have exceeded the **292.72 kg CO_2/m^3** value and the carbon impact would have significantly been increased. The crucial schedule and cold weather accommodating 24-hour and 48-hour accelerated mix designs reflect a **29.6%** and **23.5%** increase over the standard baseline respectively.

In addition, enforcing the baseline GWP would have resulted in the project schedule being severely impacted. Typically, standard mixes achieve an industry guideline of 75% at 7 days, depending on SCM contents, and the Met mixes required 24-hour and 48-hour strength enhancements. This ultimately helped the contractor to meet their schedule deadlines.

Special application baselines did still offer a reduction of 0.3% (24-hour) and 5.0% (48-hour) respectively for the accelerated mix designs, compared to the updated baseline of **380.53** kg CO_2/m^3 The set accelerated mix design allowed for a 23.1% reduction , compared to the updated baseline, due to an optimized mix design and the special baseline.

Currently, when specified GWP values are exceeded, there is no process for determining the consequences of not hitting the performance criteria and no possible way to enforce these requirements. Giving the ready mixed producer the flexibility to manage and adjust their designs by employing a CCPB not only will produce a better performing concrete, but it will also lead to a more sustainable low carbon product. The case study clearly showed that even when application specific GWP baselines were exceeded on numerous instances, the CCPB still showed an overall reduction of 11.5% on the project. The special application GWP increase of 30% is also critical here to allow the contractor to accelerate the performance of mix designs and to keep the project on schedule.

It is therefore imperative that specifiers understand the consequences of specifying application specific GWP values in a real-world project setting.

ALBERTA CASE STUDY

DEVILLE CONDOMINIUMS

CONCRETE ALBERTA

DEVELOPER: REMINGTON DEVELOPMENT CORPORATION

ALBERTA CASE STUDY

This second case study also involves a condominium development with three(3) towers. As mentioned previously, the long construction cycles of condos often results in evolving mix design requirements for schedule and constructability reasons as the project evolves. Some of these evolutions may have negative impacts on the embodied carbon of the concrete, as highlighted in the prior case study.

To help mitigate these potential impacts, project teams may consider an approach of "Carbon Value Engineering". The term "value engineering" in concrete construction is well understood. Collaborating with suppliers and contractors can often create value in terms of cost, labour, and/or schedule savings. More often than not, the best value engineering success is achieved the earlier suppliers are engaged in the project cycle.

When it comes to Concrete Carbon, the same applies. Engaging and collaborating with ready-mixed concrete suppliers early in the project process, ideally at design or pre-tender, will allow the ready-mixed concrete industry to discuss project details, assumptions, limitations, opportunities, and challenges, and convey potential carbon-reducing solutions that could be used on the project, creating more value in carbon reduction.

All images courtesy of Masson 2023

DeVille at Quarry Park Condominiums - Calgary

DeVille at Quarry Park entailed the construction of three, 13-storey residential towers, each housing one hundred or more rental units, with a shared two-level parkade. This multi-residential addition to the Quarry Park community was a result of a team effort by three key project team members, namely GGA-Architecture, Remington Development Corporation, and RJC Engineers. Construction of the $100 Million plus, 275,000 sq. ft. (25,550 sq. m.) complex was completed in three phases: tower one and parkade (completed August 2021), tower two (completed April 2022), and tower three (completed August 2022).

Though concrete construction carbon reduction goals were not a primary focus of designers and specifiers, Lafarge was afforded the opportunity to showcase a good sample of their sustainable product line. This case study's primary purpose is to demonstrate how the needs of a typical project schedule can still be met while achieving substantial concrete carbon reduction goals well below industry average baselines. Using the information provided in this guideline and already available concrete carbon resources such as EPDs, designers and specifiers can formulate a plan in collaboration with their ready-mixed concrete producer to achieve their carbon reduction goals today.

Concrete Needs of the DeVille at Quarry Park

As part of the mix design submittal and review process, eleven mix designs, including two high early strength mixes, were submitted by the ready-mix producer to the contractor. Preliminary discussions at the planning table with the ready-mixed concrete provider present reviewed scheduling and mix performance. This discussion raised the possibility that the special application high-early strength mixes might be able to be eliminated. Not only would this allow the project to reduce the number of different mix designs, this would avoid the use of higher-carbon specialty high-early strength mixes.

Initial Mix Design Submission

Mix Design	Application	Pre-Carbon Value Engineering Volumes (m^3)	Actual Project Volumes (m^3)
25MPa Non Air N-CF	Standard	428	428
32MPa in C-2	Standard	13	13
35MPa Air F-2	Standard	0	138.5
45MPa Non Air N	Standard	3575.5	3575.5
45MPa Non Air C-1	Standard	259.5	259.5
35MPa Non Air N	Standard	1570	2070
35MPa C-1	Standard	300	300
35MPa C-1	Standard	1699	1699
35MPa Non Air N*	Special	500	0
35MPa Air F-2*	Special	138.5	0
20MPa Non Air	Standard	130	130

** 25MPa in 24 hrs*

Lower Carbon Value-Engineering

Once the project got underway, early field test results, along with schedule coordination, supported the ability to eliminate the use of the high-early specialty mixes. Collaboration between ready-mixed concrete producer and project team in this regard facilitated implementation of this carbon-lowering value-engineering opportunity, as highlighted in the following table. Although not formally part of the CCPB process, it is interesting to note that the carbon-lowering value engineering discussion carried out early in the project resulted in a notable decrease in overall concrete carbon in the project.

Although not formally part of the CCPB process, it is interesting to note that the carbon-lowering value engineering discussion carried out early in the project resulted in a notable decrease in overall concrete carbon in the project.

Carbon Reduction Through Early CO_2 Value-Engineering

Mix Design	Application	Ready-Mix Supplier Type III Plant-Specific EPD GWP (kg CO_2 / m^3)	Alberta Industry-Average EPD Baseline Mix GWP (kg CO_2 / m^3)	Updated Baseline GWP (30% increase) (kg CO_2 / m^3)	Pre-Carbon Value Eng. Volumes (m^3)	Actual Project Volumes (m^3)	Pre-Value Eng CO2e Baseline (tonnes CO_2)	GWP Post Value Eng. (tonnes CO_2)
35MPa Air F-2	Standard	290	409.82	N/A	0	138.5	0	40.2
35MPa Non Air N	Standard	259	328.02	N/A	1570	2070	515.0	536.1
35MPa Non Air N*	Special	342	328.02	426.43	500	0	213.2	0.0
35MPa Air F-2*	Special	308	409.82	532.77	138.5	0	73.8	0.0
						Total:	802.0	576.3
							Lower Carbon Value Engineering Savings:	225.7

** 25MPa in 24 hrs*

Applying the CCPB Process

The previous case study, The Met in Toronto, Ontario, provides a broken out, detailed step-by-step application example of using the CCPB Process on a project.

Once familiar with the process, it is possible to apply the critical steps in a more consolidated table format.

In this case of The DeVille in Calgary, Alberta, due to the carbon-lowering value engineering performed, there are no longer any specialty mixes in the set of mix designs actually used on the project.

Also of interest in this particular case study, the ready-mixed concrete producer had Type III plant-specific EPDs available for the mixes on the project. The LCA information used to generate the EPDs was compiled and developed by Climate Earth. The program operator who validated the EPDs is ASTM International.

Given that the specifications for The DeVille were the ideal for lowering carbon, based on CSA Performance-Based standards, the ready-mixed producer was able to use many levers to lower carbon on the project. Concrete carbon footprints (GWP values) were brought below baseline Industry Averaged EPD levels by using Type GUL portland-limestone cement and Type F fly ash at minimum cement replacement rates of 25%. Construction schedules were maintained through the occasional use of chemical accelerators and by effective use of super plasticizers to increase the workability and to improve cementing materials efficiencies. The use of corrosion inhibitors was limited to only where required. The project used 56-day design targets for most of the C-1 concrete. This extended time to specified design strength allowed for a reduction of cement in the mix design and therefore lowered CO_2 in the project.

It is assumed at the start of the project, that **STEP 1: CALCULATE ANTICIPATED CO2E BASELINE** was applied. At the project close out stage, the CCPB can be analyzed to determine how the mix designs that were used impacted the overall carbon reduction goals. Using the available Type III plant-specific EPDs and a collaborative effort between the designer, contractor, and ready mixed producer, the CO2e Project can be calculated.

The following table highlights the application of the next two steps in the process, namely:

STEP 2: CALCULATE FINAL CO2E BASELINE, and

STEP 3: CO2E PROJECT CALCULATION.

Note that there is no need for **STEP 2B: ADJUST & CALCULATE ANTICIPATED CO2E BASELINE FOR ANY SPECIAL APPLICATION MIXES.**

Applying the CCPB Steps

				STEP 2		STEP 3
	Actual Project Volumes (m^3)	Alberta Industry-Average EPD Baseline Mix	Alberta Industry-Average EPD Baseline Mix GWP (kg CO_2 / m^3)	CO2e Baseline (tonnes CO_2)	Ready-Mix Supplier Type III Plant-Specific EPD GWP (kg CO_2 / m^3)	CO2e Project (tonnes CO_2)
25MPa Non Air N-CF	428	GU 10FA	306.32	131.1	232	99.3
32MPa C-2	13	GU 10FA	396.85	5.2	313	4.1
35MPa Air F-2	138.5	GU 15FA	409.82	56.8	290	40.2
45MPa Non Air N	3575.5	GU 15FA	418.44	1496.1	286	1022.6
45MPa Non Air C-1	259.5	GU 15FA	464.66	120.6	393	102.0
35MPa Non Air N	2070	GU 20FA	328.02	679.0	259	536.1
35MPa C-1	300	GU 20FA	363.13	108.9	339	101.7
35MPa C-1 @ 56d	1699	GU 20FA	363.13	617.0	308	523.3
20MPa Non Air	130	GU 10FA	260.95	33.9	128	16.6
			Total:	3248.6		2445.9

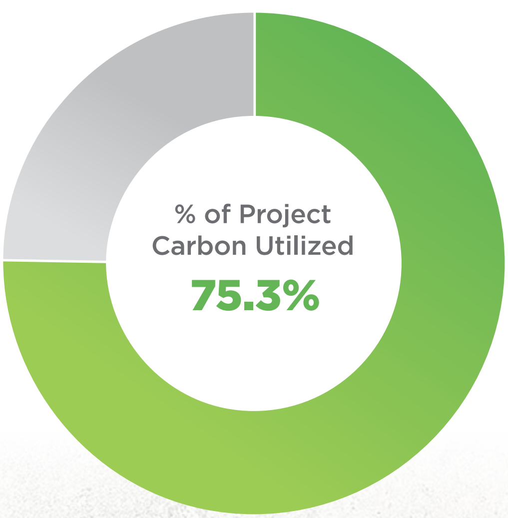
Project Summary and Specifier Considerations

Having calculated the Final CO2e Baseline and CO2e Project, the GHG Reduction in tonnes of CO_2 and % GHG Reduction for the overall project can be calculated. Applying the concept of the CCPB and following the process through the case study, The DeVille project achieved 24.7% reduction in CO_2 and if the lower carbon value engineering is considered, an additional 7% reduction was also achieved. A full summary of the Final CO2e Baseline versus the CO2e Project results are shown here.

This reduction is quite significant. The keys to achieving this level of reduction, included:

- The use of CSA Performance-Based specificiations which allowed the ready-mixed producer to effectively use SCMs, admixtures, and GUL to lower carbon and achieve better cement efficiencies,
- Later-age design strengths allowing for lower cement contents in some mixes,
- Lower-carbon value engineering by engaging in collaborative discussions with the ready-mixed producer early in the project cycle, successfully eliminating the need for special application mixes, and
- Collaborative discussions on carbon-lowering opportunities throughout the project.

Concrete Carbon Project Summary



Summary

Total Concrete Carbon Project Budget	**3,248.6 tonnes CO_2**
Total Carbon Project Impact	**2,445.9 tonnes CO_2**
Total Carbon Savings	**802.7 tonnes CO_2**
% GHG Reduction	**24.7%**

Carbon-Lowering Value Engineering investigated with the ready-mixed concrete supplier early in the project cycle reduced Concrete Carbon on this project by an additional **225.7/3248.6 = 7%.**

QUÉBEC CASE STUDY

Image courtesy of Lafond Côté Architectes

ALBÉDO AND CPE MISTIGRI

Association Béton Québec
LA référence

OWNER: GRT ACTION-HABITATION DE QUÉBEC

QUÉBEC: A SENIORS' RESIDENCE CASE STUDY

A seniors' residence project was chosen to show how a specification can evolve during the bidding process towards an efficient performance specification to maximize the number of bidders, and promote innovation and transparency in the construction of a building where the owner is keen to reduce the building's carbon footprint.

The quotation process for this project took place before the publication of the industry-average Quebec Environmental Product Declaration (EPD). At this point in time, few if any projects had been carried out with greenhouse gas reduction requirements for concrete outside the context of LEED projects.

What makes this case study project even more interesting is that the initial specifications for this project were in fact extremely prescriptive, requiring among other things, maximum distances from cement sources and maximum CO_2 emissions.

In order to open up the project to as many bidders as possible and to obtain the best results in performance and low carbon as possible, the concrete producer suggested that the designer opt for a performance-based specification. An addendum to the specification was then published, specifying an average concrete value of 300 kg/m^3 CO_2 eq. for the entire project.

ALBÉDO and CPE MISTIGRI – SAINTE-FOY

ALBÉDO is a 128-unit, 23 729 m^2 seniors' housing project, including common areas and circulation, developed under the AccèsLogis program of the Société d'habitation du Québec (SHQ), combined with a double facility of the 148-place La petite cour de Mistigri I and II daycare center in Sainte-Foy.

Photo: Christian Gingras

Construction occurred/is occurring from July 2022 through to March 2024, and the project partners were as follows:

Owner: GRT Action-Habitation de Québec
Architect: Lafond Côté Architectes
Engineer: CIME Consultants Inc.
Contractor: Concrea
Concrete producer: Provincial Concrete

The case study presents two concrete greenhouse gas reduction calculation situations based on :

- Type III product-specific environmental product declarations (EPDs) in line with ISO 14025 standards (specific EPDs)
- Type III environmental product declarations, industry average in accordance with ISO 14025 (generic EPDs)

Photo: Christian Gingras

Concrete Needs of ALBÉDO

The project required 7 main types of concrete for a total volume of approximately 7 150 m^3. Details of the mixes are provided in the following table. Some variations in these mixes may have occurred depending on site conditions:

- Superplasticizer dosage to adjust concrete slump;
- Use of accelerating or retarding admixtures, depending on atmospheric conditions; and
- Other minor modifications.

The Canadian government's Standard on Embodied Carbon in Construction was not published when the specifications were issued. As such, the calculations presented here are in fact the exact calculations used during the project and as such, none of the mix calculations presented are utilizing the "Special Application" category for greenhouse gas emissions by 130% compared with the industry average for specialized concretes (i.e. high initial strength or cold weather application).

Applying the CCPB Process

Type III Plant-Specific EPDs

As part of the project, the concrete producer provided Type III plant-specific EPDs for the different concrete formulations. The target of a maximum average of 300 kg/m^3 CO_2 eq. was achieved with an average of 276 kg CO_2 eq./m^3.

The project will have reduced CO_2 eq. emissions by 14% compared with the case where the concrete would have been delivered with the emissions associated with the industry's average mixes.

In order to open up the project to as many bidders as possible and to obtain the best results in performance and low carbon as possible, the concrete producer suggested that the designer opt for a performance-based specification.

Applications	Volume (m3)	Mix Design	Cement type	Supplementary cementitious materials Type and (%)
Mud slab	247	20 MPa Class N	GU	0%
Foundation walls, continuous footing	912	25 MPa Class N	GU	22% S
Structural slabs, columns, bracing walls	4185	30 MPa Class N; N-CF	GU	22% S
Exterior sidewalks, structural balconies,etc,	392	32 MPa Class C-2	GU	0%
Parking ramps, terrace, slabs	530	35 MPa Class C-1	GUb-F/SF	23% F and SF
Columns	40	40 MPa Class C-1	GUb-F/SF	23% F and SF
Bracing columns, walls	845	40 MPa Class N	GU and GUb-SF	4% SF

S: Ground granulated blast-furnace slag F: Type F fly ash SF: Silica fume

Final CO2e Baseline and CO2e Project Calculations with plant-specific EPDs

Applications	Volume (m^3)	GWP per m^3		GWP for project	
		Baseline Quebec IA EPD (kg CO_2 / m^3)	Ready-Mix Supplier Plant-Specific (kg CO_2 / m^3)	STEP 2 : CO2e Baseline (tonnes CO_2)	STEP 3: CO2e Project (tonnes CO_2)
Mud slab	247	264	250	65.16	61.75
Foundation walls, continuous footing	912	287	254	262.13	231.65
Structural slabs, columns, bracing walls	4185	311	265	1303.29	1109.03
Exterior sidewalks, structural balconies,etc,	392	363	388	142.22	152.10
Parking ramps, terrace, slabs	530	380	269	201.64	142.57
Columns	40	397	259	15.87	10.36
Bracing columns and walls	845	364	317	307.78	267.87
			Total:	2298.09	1975.31
			STEP 4: GHG reduction (tonnes):		322.78
			STEP 5: % GHG reduction:		14.0%
			Average GHG per m^3:	321	276

Industry-Average EPDs (hypothetical case)

If the project had been carried out hypothetically using data from Quebec's Industry-Average EPDs, the concrete used in the project would have had an average GHG of 288 kg CO_2 /m³. This value corresponds to a 10.5% reduction in the greenhouse gases associated with concrete, compared to Baseline Quebec Industry-Averages.

It should be noted that the following assumptions/approaches were used to determine the greenhouse gases associated with the proposed mixes using the Quebec Industry-Average EPD:

- Linear regressions were performed using the Quebec IA EPD to determine the GWP for each of the mixes.
- When a ternary cement containing silica fume is used, the amount of silica fume is converted to the equivalent percentage of the other cement additive used in the blended cement. In this project, the quantities of silica fume and type F fly ash give a total of 23% of supplementary cementitious materials. Calculations of CO_2 eq. emissions are therefore based on an equivalent dosage of 23% fly ash.

Calculation of GWP based on Quebec IA EPD (linear regression)

Applications	GWP per m³		GWP for project	
	Baseline Quebec IA EPD (kg CO_2 / m³)	Quebec IA EPD Mix ~ Linear Regression (kg CO_2 / m³)	STEP 2 : CO2e Baseline (tonnes CO_2)	STEP 3: CO2e Project Quebec IA EPD Mix ~ Linear Regression (tonnes CO_2)
Mud slab	264	272	65.16	67.23
Foundation walls, continuous footing	287	250	262.13	227.81
Structural slabs, columns, bracing walls	311	271	1303.29	1132.05
Exterior sidewalks, structural balconies,etc,	363	374	142.22	146.77
Parking ramps, terrace, slabs	380	313	201.64	165.68
Columns	397	325	15.87	13.02
Bracing columns and walls	364	360	307.78	304.28
		Total:	2298.09	2056.82
		% GHG reduction:		10.5%
		Average GHG per m³:	321	288

Project Summary

In the Albédo project, the specification to limit greenhouse gases to 300 kg/m³ CO_2 eq. for concrete for the entire project was met. By using mixes that refer to plant-specific EPDs, the reduction in greenhouse gases compared with the baseline mixes corresponds to 14%. If the project were hypothetically based on the generic EPDs, the associated reduction would have been 10,5%. In both cases, the project would have met the 10% minimum reduction requirement of the Canadian government's Standard on Embodied Carbon in Construction.

The Canadian government's Standard on Embodied Carbon in Construction was not published when the specifications were issued. As such, the calculations presented here are in fact the exact calculations used during the project and as such, none of the mix calculations presented are utilizing the "Special Application" category for greenhouse gas emissions by 130% compared with the industry average for specialized concretes (i.e. high initial strength or cold weather application). Carbon reductions achieved would have been even higher than 14% should these standards have been applied.

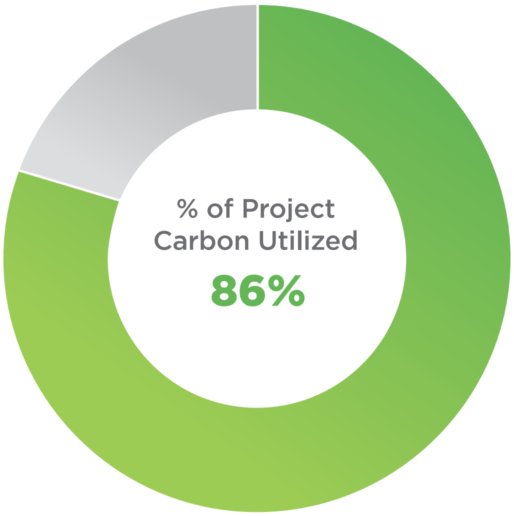
Despite this, the delays associated with cold-weather concreting on the project resulted in a delay of up to one week on the project. The various parties involved were able to adjust to minimize the impact of cold weather. Thanks to the general contractor's expertise in planning and coordinating work for winter conditions, and to the work crews who all pitched in during winter storms, the schedule was kept virtually to the day.

In summary, this case study provides an excellent example of the value of using PERFORMANCE-BASED SPECIFICATIONS utilizing the CONCRETE CARBON PROJECT BUDGET (CCPB) process. Target an overall project-level reduction in greenhouse gases compared with the baseline average, right from the start of the project. For example, require a minimum reduction of 10% (or other percentages) in greenhouse gases associated with concrete, compared with the baseline average, and apply this reduction on a total project-level.

Image courtesy of Lafond Côté Architectes

When specifications specify greenhouse gas reduction requirements in performance-based rather than prescriptive form, ready-mixed concrete producers are able to bring to bear all proven concrete carbon-reducing levers while meeting performance and durability requirements of a concrete-construction project and encouraging better free market competition and innovation.

Concrete Carbon Project Summary



Summary

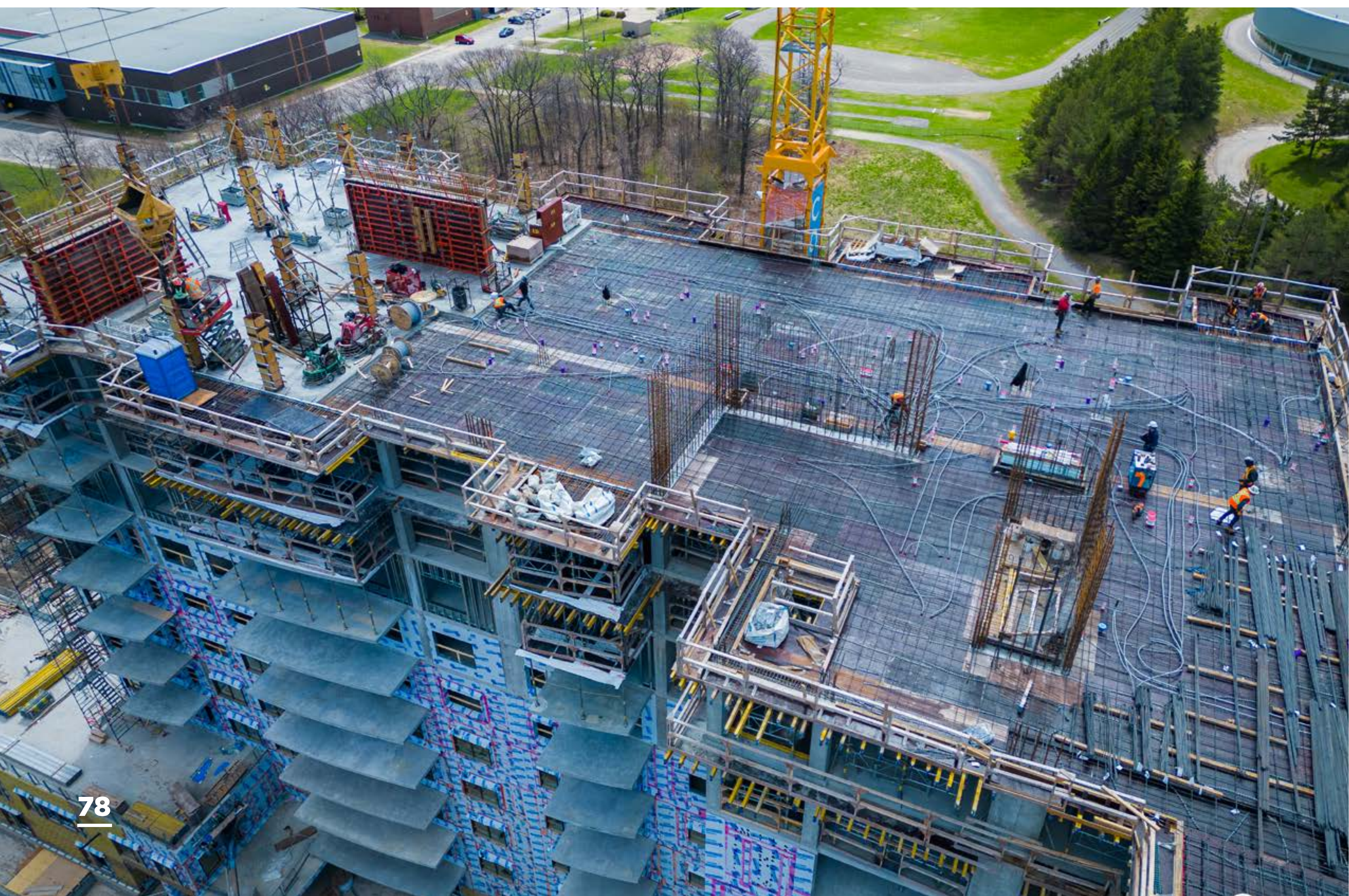
Total Concrete Carbon Project Budget
2,298.1 tonnes CO_2

Total Carbon Project Impact
1,975.3 tonnes CO_2

Total Carbon Savings
322.8 tonnes CO_2

% GHG Reduction
14.0%

Photo: Christian Gingras



BRITISH COLUMBIA
CASE STUDY

Photo: hcma architecture + design | WHM Structural Engineers

HENRY HUDSON SCHOOL

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BRITISH COLUMBIA: HENRY HUDSON SCHOOL CASE STUDY

The following case study highlights how collaboration between project teams and ready-mix concrete suppliers can contribute to owners/developers' achievement of potential government required carbon-reductions versus functionally-equivalent baselines.

In this example in British Columbia, the Henry Hudson School Project in the Kitsilano Neighborhood is highlighted.

Photo: hcma architecture + design | WHM Structural Engineers

Project information is as follows:

Project volume: $45 million replacement project

Location: Henry Hudson Elementary School, 1551 Cypress St, Vancouver, BC V6J 3L3

Size: Three-storey building, first two levels for school use, third level for a "neighbourhood learning centre" – a major childcare facility

Capacity: 400 students, 69 childcare space

This $45 million project is scheduled for completion by Spring 2025.

The project involves the construction of a three-storey building, with the first two levels dedicated to school use and the third level designated as a "neighbourhood learning centre." This innovative space will serve as a major childcare facility, accommodating 400 students and providing 69 childcare spaces to meet the needs of the local community.

Photo: hcma architecture + design | WHM Structural Engineers

By integrating modern design concepts and sustainable building practices, the Henry Hudson Elementary School Replacement Project aims to create a stimulating learning environment while also promoting community engagement and support.

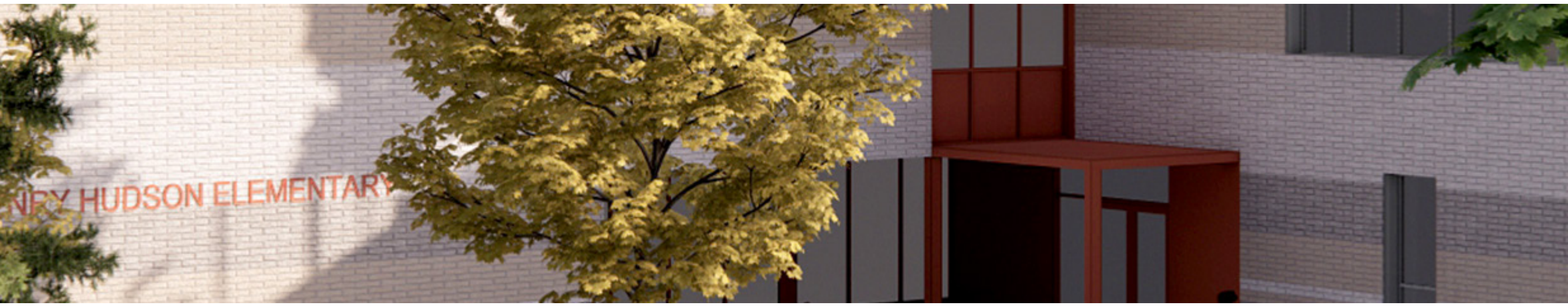
Although not in effect at time of construction, the project is expected to meet and exceed the embodied carbon guidelines outlined by The City of Vancouver Building Bylaw, which comes into effect January 1, 2025.

This case study will use the Treasury Board of Canada's "Concrete Carbon Project Budget" method, as explained in-depth in this CONCRETE CARBON: A Guideline for Specifying Low Carbon Ready Mixed Concrete in Canada document to calculate the achieved embodied carbon concrete reduction contribution as compared to a functionally-equivalent baseline using third-party verified EPDs.

Concrete Need for the Henry Hudson School

The School Board in Vancouver, British Columbia, has ***made a strategic decision to transition from a prescriptive specification to a performance-based approach*** for the Henry Hudson Elementary School project. This shift aims to achieve a seismically-upgraded and authentically sustainable solution for their new three-storey building.

In collaboration with Heidelberg Materials representatives and contractor Heatherbrae Builders, the Vancouver Project Office reviewed and approved the use of approximately 2,700 m^3 EvoBuild™ low carbon concrete. This decision aligns with the City of Vancouver's specifications, particularly focusing on Global Warming Potential (GWP) values for each concrete element, ensuring sustainability and performance goals are met.



The following summary outlines the mix designs and corresponding applications of the concrete scheduled for placement in this project:

Mix Design	Application
35 MPa Class S-3	Raft Slab Thickening and Raft Slab
25 MPa Class F-2	Concrete Wall
30 MPa Class F-2	Concrete Column
35 MPa without air	Suspended Slab
32 MPa Class C-2	Housekeeping Pads
25 MPa without air	Stairs

Applying the CCPB Process

STEP 1: CALCULATE ANTICIPATED CO2E BASELINE

The anticipated CO2e Baseline for the project is determined using the Concrete BC Member Industry-wide Environmental Product Declaration (EPD) for ready-mixed concrete (July 27, 2022 [EPD348]). The following table presents the anticipated CO2e Baseline calculations based on mix designs and anticipated volumes:

Mix Design	Anticipated Volume (m^3)	BC Industry-Average EPD Baseline Mix GWP (kg CO_2)	CO2e Baseline (tonnes CO_2)
25 MPa non-air	22	219.70	4.8
25 MPa with air	435	230.52	100.3
30 MPa with air	77	269.83	20.8
32 MPa with air	6	285.31	1.7
35 MPa with air	797	310.51	247.5
35 MPa non-air	1422	293.75	417.7
Total	**2759**	**Total CO2e Baseline**	**792.8**

The anticipated CO2e Baseline for this project amounts to 792.8 tonnes of CO2e.

STEP 2: CALCULATE FINAL CO2E BASELINE

To calculate the final CO2e Baseline, actual volumes and mix designs used in the project are required. The subsequent section details the Concrete Carbon Project Budget (CCPB) based on real volumes and mix designs employed in the project.

Mix Design	Anticipated Volume (m^3)	BC Industry-Average EPD Baseline Mix GWP (kg CO_2)	CO2e Baseline (tonnes CO_2)
25 MPa non-air	0	219.70	0
25 MPa with air	54	230.52	12.4
30 MPa with air	0	269.83	0
32 MPa with air	0	285.31	0
35 MPa with air	849.8	310.51	263.9
35 MPa non-air	1827.2	293.75	536.7
Total	**2731**	**Total CO2e Baseline**	**813.1**

It should be noted there is no requirement for Step 2B: ADJUST & CALCULATE ANTICIPATED CO2E BASELINE FOR ANY SPECIAL APPLICATION MIXES as there are no mixes on this project that fit that category.

STEP 3: CO2E PROJECT CALCULATION

The CO2e Project calculation uses actual volumes and the EPD value associated with the actual mixes. In this case, the ready-mixed concrete supplier had Type III plant-specific EPDs available for the mixes on the project. The following table presents the actual volumes and corresponding CO2e Project values for each mix design used in the project:

Photo: hcma architecture + design | WHM Structural Engineers

Mix Design		Actual Volumes (m^3)	Ready-Mix Supplier Plant-Specific Type III EPD GWP (kg CO_2)	CO2e Project (tonnes CO_2)
25 MPa with air	GENERAL 25MPA 20MM F2 5% EVB*	47	199	9.4
25 MPa with air	GENERAL 25MPA 14MM F2 5% EVB*	7	199	1.4
30 MPa with air	–	0	–	–
32 MPa with air	–	0	–	–
35 MPa with air	GENERAL 35MPA 14MM C1 6% EVB*	262.5	257	67.5
35 MPa with air	GENERAL 35MPA 14MM F2 5% EVB*	23.6	248	5.9
35 MPa with air	GENERAL 35MPA 20MM C1 6% EVB*	556.1	257	142.9
35 MPa with air	WG GEN 35MPA 20MM C1 6% 56D	7.6	199	1.5
25 MPa non-air	–	0	–	–
35 MPa non-air	GENERAL 35MPA 20MM N EVB*	1505.2	235	353.7
35 MPa non-air	GENERAL 35MPA 14MM N EVB*	322	235	75.7
Total:		**2731**		**657.9**

(* EVB = Heidelberg Materials EvoBuild™)

For this project, a total of 2,731 m^3 of concrete were supplied, resulting in a total CO2e Project of 657.9 tonnes.

Project Summary

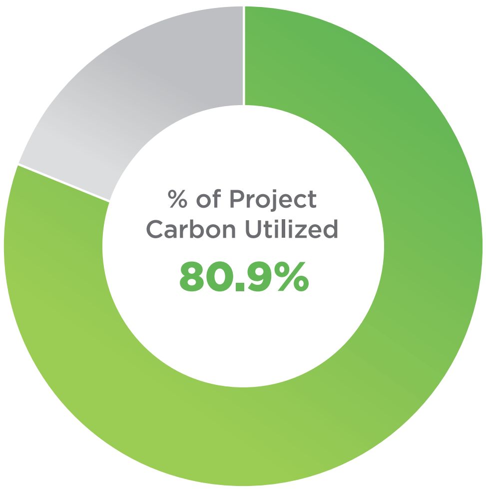
Having calculated the Final CO2e Baseline and CO2e Project, the GHG Reduction in tonnes of CO_2 and % GHG Reduction for the overall project can be calculated.

GHG Reduction = 813.1 – 657.9 = 155.2 tonnes

% GHG Reduction = (155.2*100)/813.1 = 19.1%

Applying the concept of the CCPB and following the process through the case study, the Henry Hudson School project achieved a notable 19.1% reduction in CO_2. A full summary of the Final CO2e Baseline versus the CO2e Project results is shown here.

Concrete Carbon Project Summary



Summary

Total Concrete Carbon Project Budget
813.1 tonnes CO_2

Total Carbon Project Impact
657.9 tonnes CO_2

Total Carbon Savings
155.2 tonnes CO_2

% GHG Reduction
19.1%

Despite using a higher volume of higher-specified strength concrete than initially planned, the overall Concrete Carbon Project Budget (CCPB) was successfully reduced by 19%.

Importantly, this reduction was achieved without major alterations to the project schedule or scope, highlighting the feasibility and benefits of using low carbon concrete in construction projects and the importance of:

- The use of CSA Performance-Based specifications which allowed the ready-mixed producer to effectively use SCMs, admixtures, GUL, and other levers to lower carbon in their own innovative and branded approach, and
- Collaborative dialogue between the project team and the ready-mixed concrete supplier before and during the project.

This reduction is quite significant, especially if taken in the context of the forecasted January 1, 2025 City of Vancouver Building Bylaw requirements, which are set to be finalized in 2024 and will require projects to demonstrate a whole-building embodied carbon reduction as compared to a functionally-equivalent baseline.

Specifier Resources

CRMCA provincial member assoications offer complimentary support and specification reviews regarding low carbon concrete. In-person or virtual presentations can be scheduled on-demand.

Please contact members of the applicable provincial team for more information:

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CONCRETE CARBON

A GUIDELINE FOR SPECIFYING LOW CARBON READY MIXED CONCRETE IN CANADA

CRMCA
Canadian Ready-Mixed Concrete Association
Association Canadienne du Béton Préparé

OCTOBER 2023