

# Concrete & Cement Sustainability Initiatives

Jasper Place Library, Edmonton, AB. Architect: HCMA Architecture + Design



# What is **Low Carbon Concrete**?

- Low carbon concrete refers to concrete produced with a **lower carbon footprint** than traditional mix designs, **while still meeting all relevant performance requirements**
  - Strength, permeability, durability, etc.
- To employ low carbon concrete:
  - Use available lower carbon impact materials
  - Mix design optimization (Admixtures)
  - Carbon mineralization technology
  - Tools to quantify the carbon impact (EPDs)
  - Project carbon budgeting

# Environmental Product Declarations (EPDs)



# Environmental Product Declarations

- EPDs for concrete are much like nutrition labels for common foods
- EPDs outline the impact a certain concrete mix design has on the environment
- Most important metric is the Global Warming Potential (GWP) which is calculated in kg CO<sub>2</sub>/m<sup>3</sup>

## Food Nutritional Labels

Health Impacts

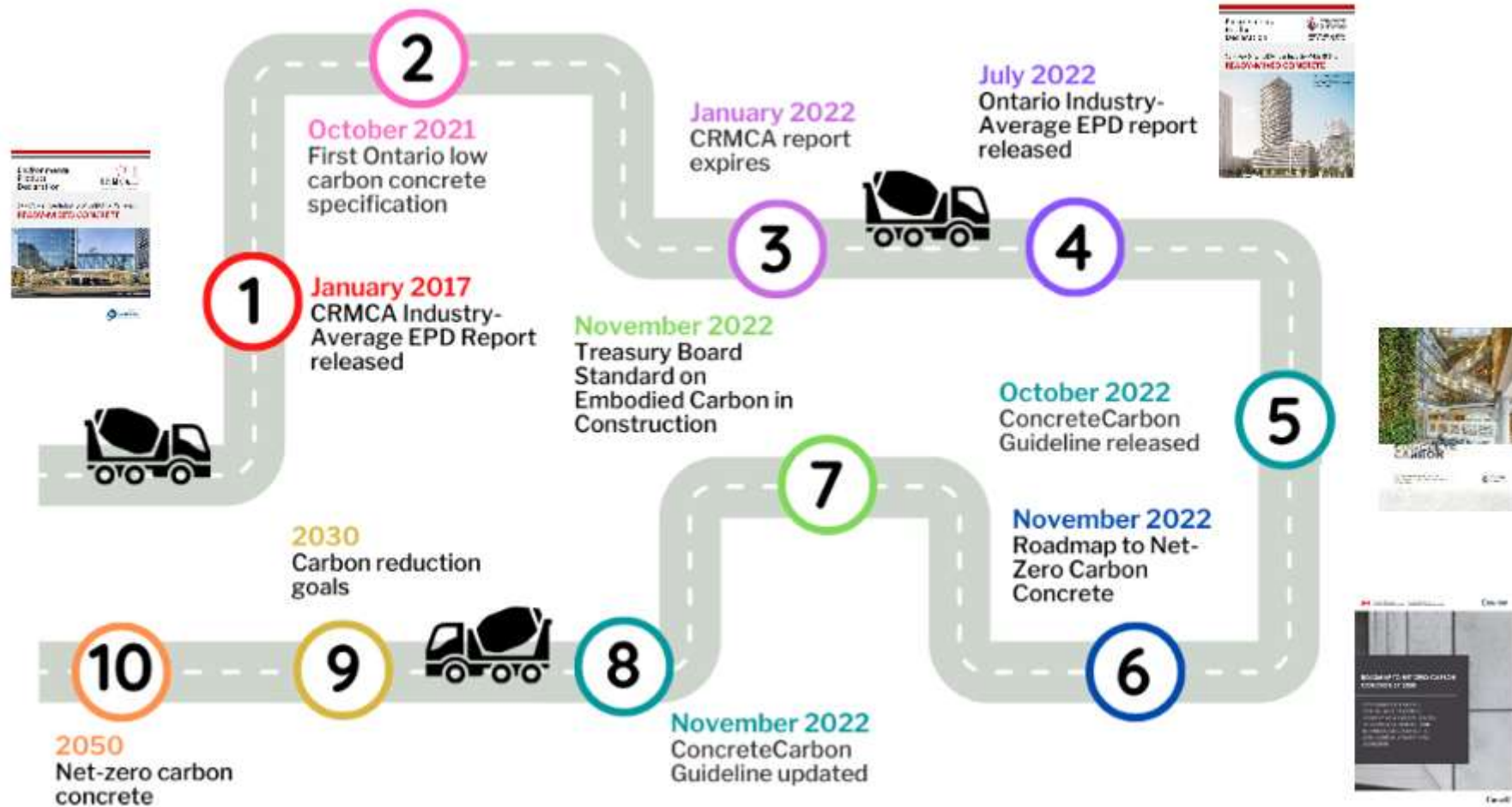
Nutrition Facts	
Serving Size 2/3 cup (55g) Servings Per Container About 8	
Amount Per Serving	
<b>Calories</b> 230	Calories from Fat 40
% Daily Value*	
<b>Total Fat</b> 8g	12%
Saturated Fat 1g	5%
Trans Fat 0g	
<b>Cholesterol</b> 0mg	0%
<b>Sodium</b> 160mg	7%
<b>Total Carbohydrate</b> 37g	12%
Dietary Fiber 4g	16%
Sugars 1g	
<b>Protein</b> 3g	
Vitamin A	10%
Vitamin C	8%
Calcium	20%
Iron	45%
*Percent Daily Values are based on a diet of 2,000 calories. Your daily values may be higher or lower depending on your calorie needs.	
	Calories: 2,500 2,500
Total Fat	Less than 65g 60g
Sol Fat	Less than 20g 20g
Cholesterol	Less than 300mg 300mg
Sodium	Less than 2,400mg 2,400mg
Total Carbohydrate	300g 375g
Dietary Fiber	25g 30g

## Product EPDs

Environmental Impacts

Environmental Impacts	
Declared Product: Mix 4FD5C5Q1 + Bode Plant EF50 Gen Use 4" line w/c .50 Compressive strength: 4000 psi at 28 days	
Declared Unit: 1 m <sup>3</sup> of concrete	
Global Warming Potential (kg CO <sub>2</sub> e)	272
Ozone Depletion Potential (kg CFC-114e)	1.6E-6
Acidification Potential (kg SO <sub>2</sub> e)	2.06
Eutrophication Potential (kg N(e))	0.27
Photochemical Smog Creation Potential (kg O <sub>3</sub> e)	0.28
Total Primary Energy Consumption (MJ)	1,577
Nonrenewable (MJ)	1,566
Renewable (MJ)	73.7
Total Concrete Water Consumption (m <sup>3</sup> )	0.69
Batching Water (m <sup>3</sup> )	0.69
Washing Water (m <sup>3</sup> )	1.8E-5
Nonrenewable Material Resource Consumption (kg)	2,464
Renewable Material Resource Consumption (kg)	1.57
Hazardous Waste Production (kg)	0.01
Nonhazardous Waste Production (kg)	-2.76
Product Components: crushed aggregate (ASTM C33), Portland cement (ASTM C150), slag cement (ASTM C98), fly ash (ASTM C618), admixture (ASTM C664), both water (ASTM C900)	

# Evolution of Low Carbon Concrete in Ontario





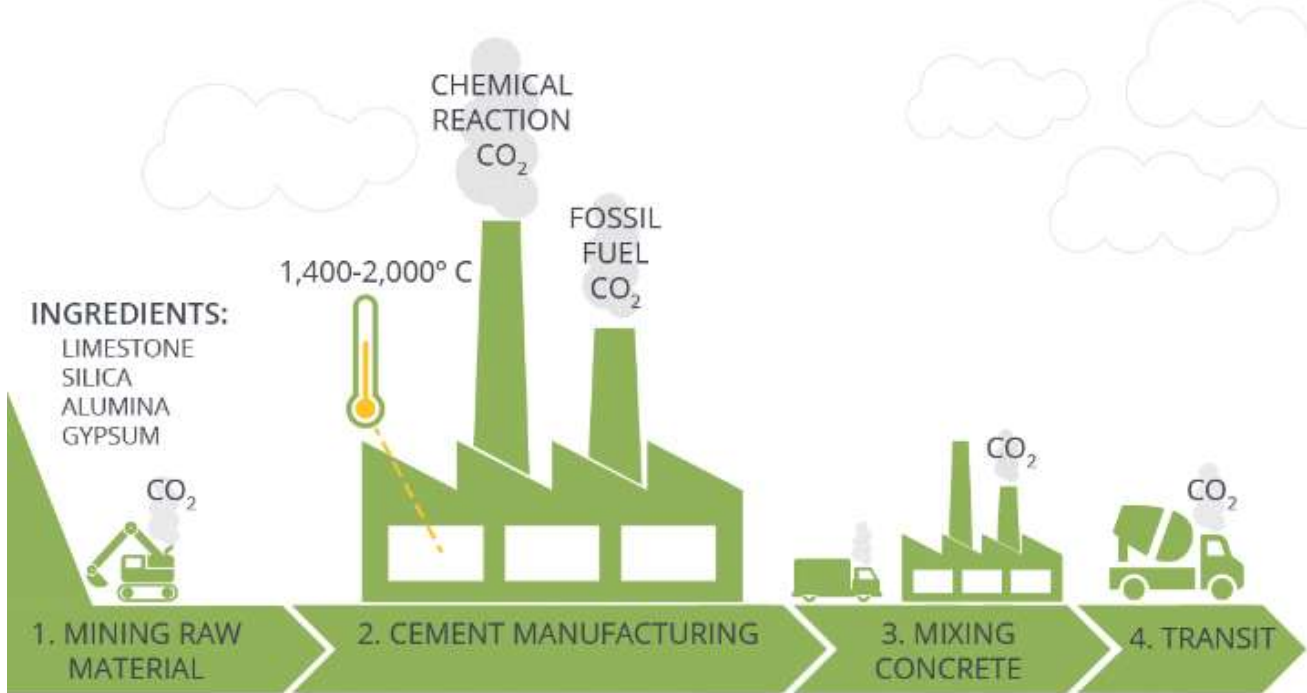
# Concrete Ontario Member Industry-Wide EPD for Ready-Mixed Concrete



Building Life Cycle Information Modules															
Product stage			Construction Process stage		Use stage							End-of-life stage			
Raw Material supply	Transport	Manufacturing	Transport	Construction/Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	De-Construction	Transport	Waste processing	Disposal
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4

Figure 1: Life cycle stage schematic – alpha-numeric designations as per NSF PCR 2021

# 2022 Concrete Ontario Report Scope A1-A3



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A1

A2

A3

# 2022 Concrete Ontario Report Mix Designs





# 2022 Concrete Ontario Report

## Mix Designs

- **23 mix designs** were chosen to represent the Ontario ready-mix industry
- Mix designs are **fully representative of the OBC and CSA A23.1 Tables 1 and 2 – Exposure Classes** performance requirements
- Slag replacement levels between **0-50%**
- Baselines were set based on average Ontario cement content and slag usage in 2021 for each mix design (Type GU as base cement)

# 2022 Concrete Ontario Report Mix Designs

**Table 18. LCA Results 30 MPa concrete with air & 0.50w/cm (F-1)**

Unit	Baseline 30MPa concrete with air & 0.50 w/cm (F-1) GU 15 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GU	30 MPa concrete with air & 0.50 w/cm (F-1) GU 15 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GU 25 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GU 35 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GU 50 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GUL	30 MPa concrete with air & 0.50 w/cm (F-1) GUL 15 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GUL 25 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GUL 35 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GUL 50 SL	
<b>Environmental impacts</b>												
GWP	kg CO <sub>2</sub> eq.	292.72	329.02	292.72	268.52	244.32	208.02	307.08	274.07	252.07	230.06	197.05
ODP	kg CFC-11 eq.	7.74E-06	7.57E-06	7.74E-06	7.86E-06	7.97E-06	8.15E-06	7.23E-06	7.45E-06	7.60E-06	7.75E-06	7.98E-06
EP	kg Neq.	0.23	0.25	0.23	0.22	0.21	0.20	0.23	0.22	0.21	0.20	0.19
AP	kg SO <sub>2</sub> eq.	1.40	1.45	1.40	1.36	1.32	1.26	1.38	1.33	1.30	1.27	1.23
POCP	kg O <sub>3</sub> eq.	23.58	23.86	23.58	23.39	23.20	22.92	22.85	22.72	22.63	22.55	22.42
<b>Use of primary resources</b>												
RPR <sub>E</sub>	MJ, NCV	82.80	91.24	82.80	77.18	71.56	63.13	90.98	82.59	76.99	71.40	63.00
RPR <sub>M</sub>	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR <sub>E</sub>	MJ, NCV	1798.64	1865.83	1798.64	1753.84	1709.04	1641.85	1765.03	1712.95	1678.24	1643.52	1591.45
NRPR <sub>M</sub>	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

**Baselines are critical to set and achieve carbon reduction goals**



# GWP Reductions from 2017 to 2022

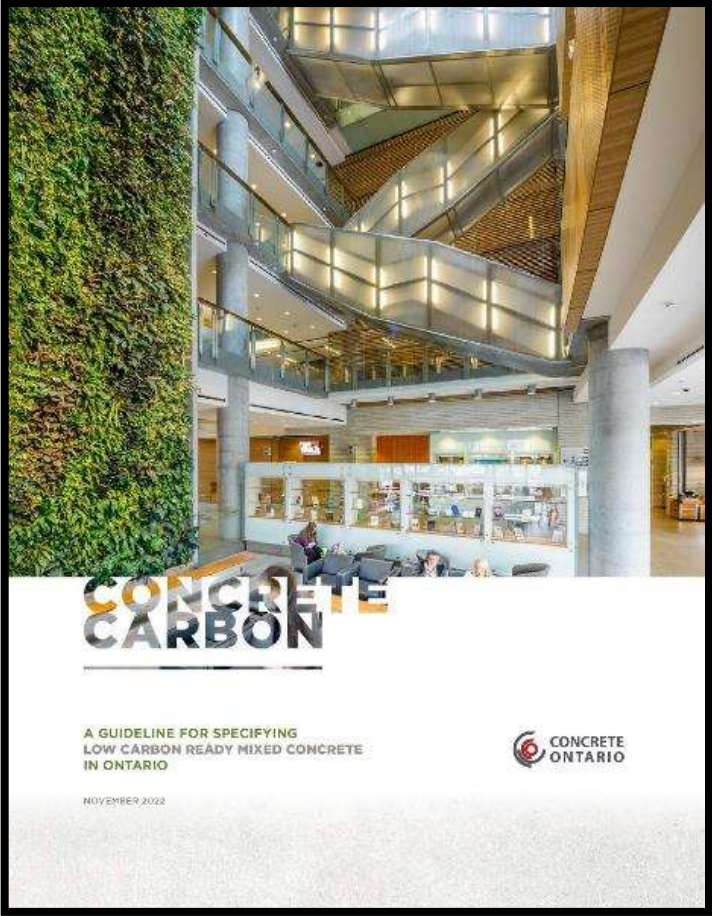
CRMCA EPD Report Benchmark 2017	Ontario EPD Report Baseline 2022	% Reduction
<b>25 MPa Industry Average Benchmark with air</b> <b>(6% SL, 4% FA)</b> 304.52 kgCO <sub>2</sub> /m <sup>3</sup>	<b>Baseline 25 MPa concrete with air &amp; 0.55 w/cm (F-2) GU 10 SL</b> 260.64 kgCO <sub>2</sub> /m <sup>3</sup>	<b>14.4</b>
<b>30 MPa Industry Average Benchmark with air</b> <b>(6% SL, 4% FA)</b> 349.68 kgCO <sub>2</sub> /m <sup>3</sup>	<b>Baseline 30 MPa concrete with air &amp; 0.50 w/cm (F-1) GU 15 SL</b> 292.72 kgCO <sub>2</sub> /m <sup>3</sup>	<b>16.3</b>
<b>35 MPa Industry Average Benchmark with air</b> <b>(6% SL, 4% FA)</b> 417.05 kgCO <sub>2</sub> /m <sup>3</sup>	<b>Baseline 35 MPa concrete with air</b> <b>GU 15 SL</b> 334.49 kgCO <sub>2</sub> /m <sup>3</sup>	<b>19.8</b>
<b>40 MPa Industry Average Benchmark with air</b> <b>(6% SL, 4% FA)</b> 458.98 kgCO <sub>2</sub> /m <sup>3</sup>	<b>Baseline 40 MPa concrete with air</b> <b>GU 15 SL</b> 361.65 kgCO <sub>2</sub> /m <sup>3</sup>	<b>21.2</b>
<b>45 MPa Industry Average Benchmark without air</b> <b>(6% SL, 4% FA)</b> 426.33 kgCO <sub>2</sub> /m <sup>3</sup>	<b>Baseline 45 MPa concrete without air</b> <b>GU 15 SL</b> 349.88 kgCO <sub>2</sub> /m <sup>3</sup>	<b>17.9</b>

2022 - 2027 % Reductions?  
 Cement industry innovations  
 Complete switchover to Type GUL





# CONCRETECARBON: Guideline for Specifying Low Carbon Ready Mixed Concrete in Ontario (November 2022)



# So How Do I Produce Low Carbon Concrete?

## Concrete Plant Factors:

- Raw Materials
- Raw Material Transportation
- Diesel Fuel Usage
- Natural Gas / Fuel Oil Usage
- Electricity

## Raw Materials (kg CO<sub>2</sub>/tonne):

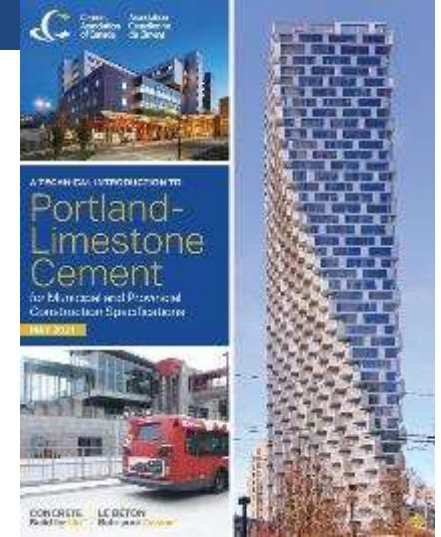
- **GU Cement** = 880
- **GUL Cement** = 780
- **Slag** = 150
- **Aggregates** = 30
- **Fly Ash** = 10
- **Admixtures** = 1
- **Water** = 1



# Producing Low Carbon Concrete

## Evaluating all your Raw Materials

- Utilize raw material EPDs
- Utilize local materials
- Evaluate the cement type



### GU VS. GUL



\*6.5% GWP reduction

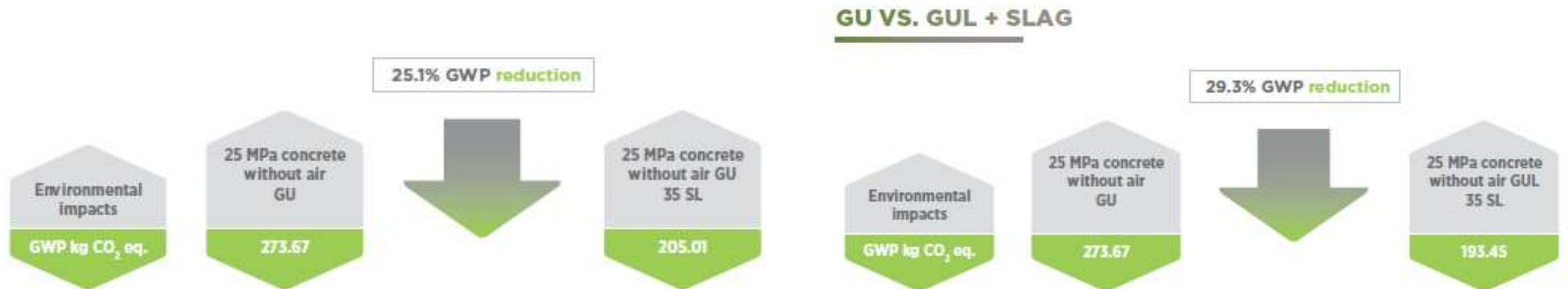


\*Up to 10% reduction possible

# Producing Low Carbon Concrete

## Maximize the Use of Supplementary Cementitious Materials (SCMs)

- Cement Type & SCM usage can result in dramatic reductions





# Producing Low Carbon Concrete

## Maximize the Use of Supplementary Cementing Materials (SCMs)

- Slag is the primary SCM in Ontario
- Silica Fume & Fly Ash can also be used
- New & innovative products are coming to market



# Producing Low Carbon Concrete

## Optimize Aggregates

- Larger Aggregate Size:
  - Lower paste content versus more challenging placement conditions
- Aggregate Gradation Optimization
- Recycled Concrete Aggregates



# Producing Low Carbon Concrete

## Utilize Chemical Admixtures

- Water reduction
- Improved placeability
- Innovative performance and carbon reduction products





# Specifying Low Carbon Ready Mixed Concrete in Ontario



# Performance-Based Specifications

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**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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# Performance-Based Specifications

## Two Options in CSA A23.1/.2

### 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.

### 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 low carbon concrete AND to achieving low carbon concrete.



# Performance-Based Specifications

## CSA A23.1 Table 5 – Owner Responsibilities

- Exposure Class
- Strength at Age (e.g., 35 MPa at 56 days)
- Required durability criteria (e.g., Maximum 0.40 w/cm, Class C-1)
- Additional criteria for durability (AVS, RCP, Shrinkage Limits, etc.)
- Architectural Requirements (e.g., Colour, surface finish, etc.)
- Pre-qualification or verification criteria (i.e., Low Permeability, Low Shrinkage, etc.)
- Any other properties that might be required to meet the owner's performance criteria



# What Does This Mean for the Concrete Producer?

Element	Compressive Strength (MPa) 28 days U.N.O.	Class of exposure (CSA A23.1 Table 1 & 2)	Maximum water-to-cementitious materials ratio	Nominal maximum sizes of coarse aggregate (mm)	Air content category (CSA A23.1 Table 2)	Range in air content (%) (CSA A23.1 Table 4)	Ontario Industry-Average EPD Baseline Mix GWP (kgCO <sub>2</sub> /m <sup>3</sup> )
Footings	30 MPa (56 days)	N	--	20	--	--	264.38
Slab on grade (interior)	25 MPa	N-CF	0.55	20	--	--	264.94
Exterior columns (exposed)	25 MPa	F-2	0.55	20	2	4-7	260.64
Slab on grade (exterior)	32 MPa	C-2	0.45	20	1	5-8	326.46
Foundation walls (exposed)	30 MPa	F-1	0.50	20	1	5-8	334.49
Retaining/Foundation walls/shear walls (exposed)	35 MPa	F-2	0.55	40	2	3-6	334.49
Shear walls (not exposed)	35 MPa	N	--	20	--	--	295.46
Columns (exposed)	35 MPa (56 days)	C-1	0.40	20	1	5-8	313.07
Architectural columns (exposed) SCC	35 MPa (56 days)	C-1	0.40	10	1	6-9	377.33
Topping on steel deck	25 MPa	N	--	10	--	--	254.05
Mechanical housekeeping pads	20 MPa	N	--	20	--	--	220.29

# Producing Low Carbon Concrete

## Communication & Evaluation

- Schedule
- Placement method
- Special applications





# Challenges For the Concrete Producer

- Specifications
- Weather Impacts
- Contractor Requirements
- Field Testing Variability
- Raw Material Availability



# Thank you!

