SCA
SLAG CEMENT ASSOCIATION

Slag Cements Role in Sustainable Concrete

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SCA SLAG CEMENT ASSOCIATION

Member Company

Professor
Doug Hooton

aci

Agenda

Overview of Performance Benefits

- Defining & the specifications
- Positive effects in concrete
- Durability benefits

Overview of Sustainable Benefits

- Goal to net zero using Slag and PLC
- Conveying lower carbon benefits
- Measurement tools to convey lower carbon concrete message

SCMs: Why Complicate the Mix?

(If portland cement has worked, why add Supplementary Cementitious Materials such as Slag cement?)

1. To **use up Ca(OH)2 byproduct** of cement hydration to form more Calcium-Silica Hydrates (C-S-H)
2. To strengthen the **aggregate/paste bond** in the Interfacial Transition Zones (ITZ) around aggregate
3. To **remove excess alkalis** from pore water
4. To increase binding of chloride ions in aluminate phases
5. To increase sulfate resistance
6. To help **lower heat of hydration.**
7. To reduce “energy” & environmental footprint

Slag Cement Specifications

Slag Cement in Concrete

Standard Specifications

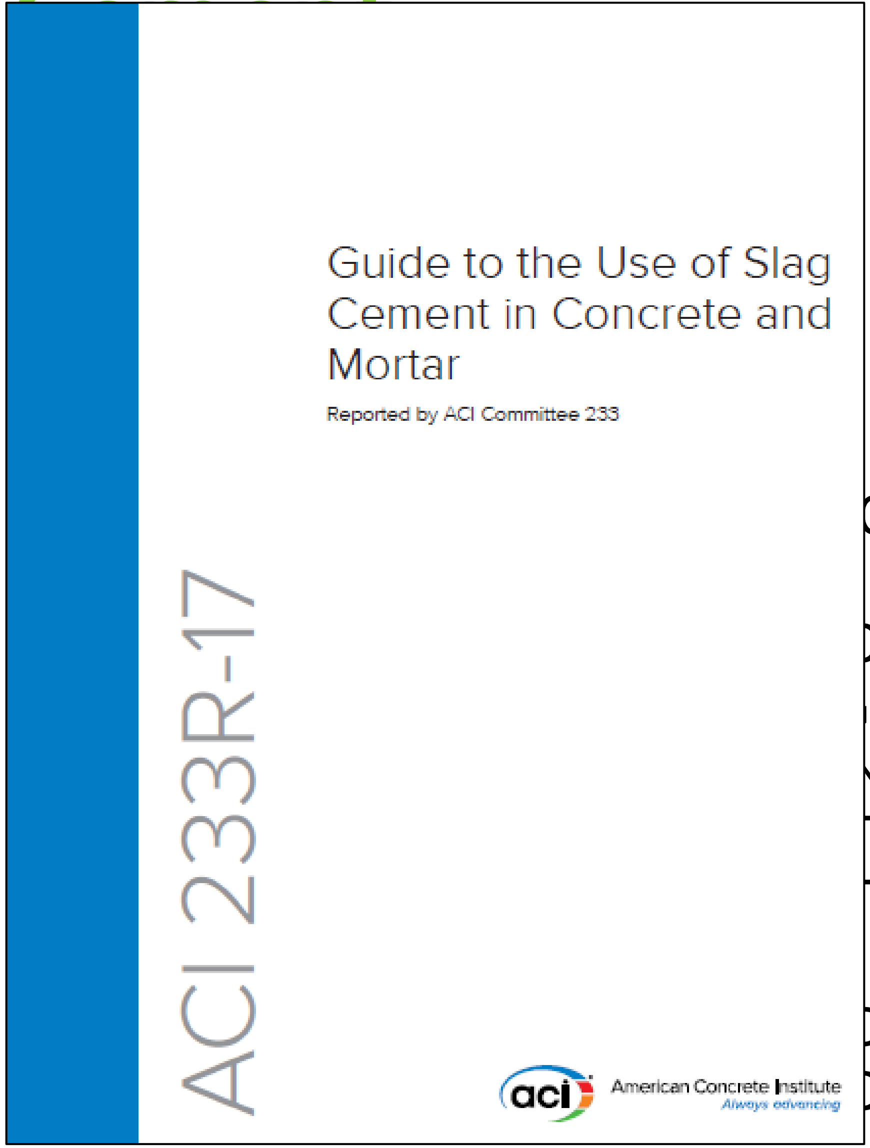
Slag cement as a constituent of blended cement

- **ASTM C595** or **AASHTO M 240** Standard Specification for Blended Hydraulic Cements
  - Type IS(35) = 65% PC + 35% Slag
  - Type IT(S25)(P15) = 60% PC + 25% Slag + 15% Pozzolan
  - Type IT(S25)(L10) = 65% PC + 25% Slag + 10% Limestone

Slag cement as an SCM in concrete

- **ASTM C989** or **AASHTO M 302** Standard Specification for Slag Cement for Use in Concrete and Mortar or **CAN/CSA-A3000-98** Cementitious Materials Compendium

Reference Guide on Slag


Guide to the Use of Slag Cement in Concrete and Mortar

Reported by ACI Committee 233

ACI 233R-17

American Concrete Institute
Always advancing

ON

ODUCT TYPES
, AND BATCHING
NCRETE CONTAINING SLAG CEMENT
TIES OF FRESH CONCRETE
TIES OF HARDENED CONCRETE AND

CATIONS
OPMENT

A good document to start with

PLC for Special Properties

Cement modifiers

- Sulfate resistance – MS, HS
  - Sulfate-containing soils
  - Sulfate-containing groundwaters
- Heat of hydration – LH, MH
  - For mass concrete placements
  - No counterparts in CSA
- High-early strength – HE
  - For precast concrete
  - New in August 2021

Cement type	OPC C150 (M 85)	PLC C595 (M 240)	PLC CSA A3000
General use	I	IL	GUL, GULb
moderate sulfate resistance	II, II(MS)	IL(MS)	MSL
moderate heat of hydration	II(MH)	IL(MH)	-
high sulfate resistance	V	IL(HS)	HSL
low heat of hydration	IV	IL(LH)	-
high-early strength	III	IL(HE)	HEL, HELb

Next Evolution and transition towards zero

Current

- PLC

Future

- IT Limestone blend with slag or scm
- High Early Limestone PLC HE

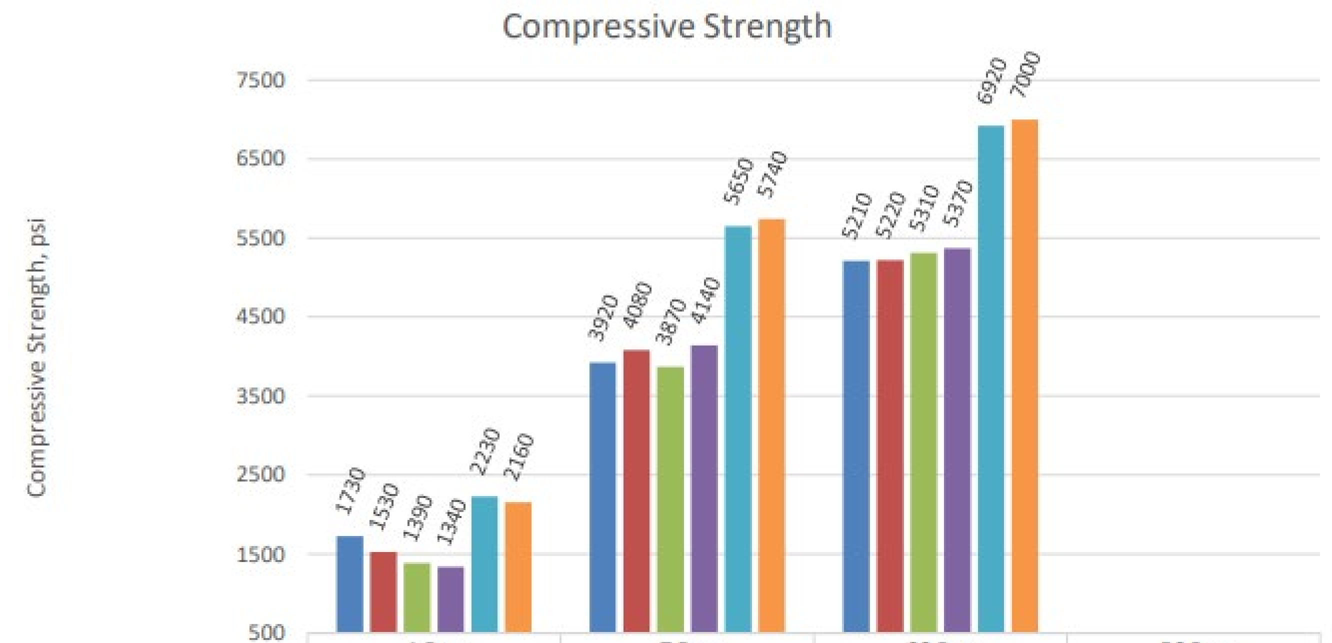
- New SCM's
  - Calcined clays
  - Volcanic ash
  - Ground glass
  - Harvested ash

ASTM C595 Ternary blend slag with limestone

Concrete compressive strength

Legend

- Low strength mixes (505lb w/cm 0.56)
  - IT 15% slag 12% limestone
  - Plc 15% slag addition
  - IT 12% slag addition
  - Plc 25% slag addition
- High Strength mixes (611lb w/cm 0.46)
  - IT 15% slag 12% limestone
  - Plc 15% slag addition



	1 Day	7 Day	28 Day	56 Day
IT	1730	3920	5210	
PLC / 15% Slag	1530	4080	5220	
IT / 12% Slag	1390	3870	5310	
PLC / 25% Slag	1340	4140	5370	
High CMT IT / 12% Slag	2230	5650	6920	
High CMT PLC / 25% Slag	2160	5740	7000	

IT | PLC / 15% Slag | IT / 12% Slag | PLC / 25% Slag | High CMT IT / 12% Slag | High CMT PLC / 25% Slag

*

EPD- envirocemplus vs envirocem

Core environmental impact indicators

A1-A3. Product

Indicator	DET Cement (Type IT (L12) (S15)) - 2022 data - final	DET Cement (Type IL) - 2022 data - final	Unit
Global warming potential	669.8	805.3	kg CO_2 eq.
Global warming potential, biogenic	0.3569	0.4532	kg CO_2 eq.
Depletion potential of the stratospheric ozone layer	1.729E-5	2.014E-5	kg CFC 11 eq.
Acidification potential of soil and water sources	5.315	6.402	kg SO_2 eq.
Eutrophication potential	0.6882	0.8423	kg N eq.
Photochemical oxidant creation potential	39.87	47.82	kg O_3 eq.
Abiotic depletion potential for non-fossil mineral resources	9.458E-5	1.110E-4	kg Sb eq.
Abiotic depletion potential for fossil resources	3398	4041	MJ, net calorific value

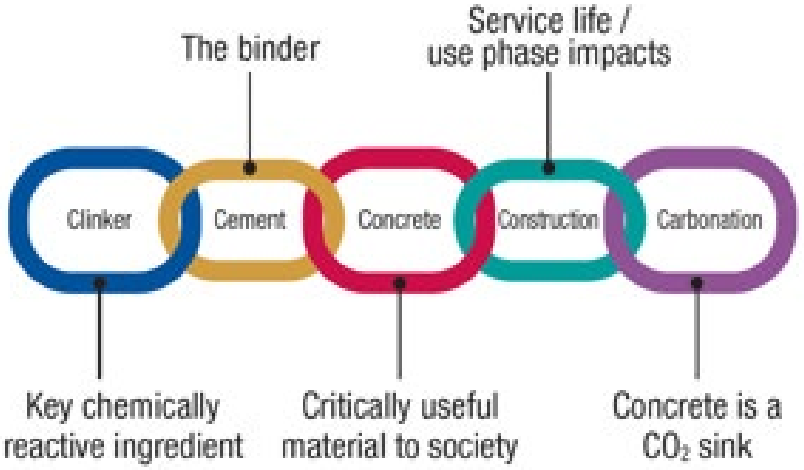
General Overview of Sustainable Benefits from Slag Cement Concrete

2050 Road maps to carbon Neutrality in concrete

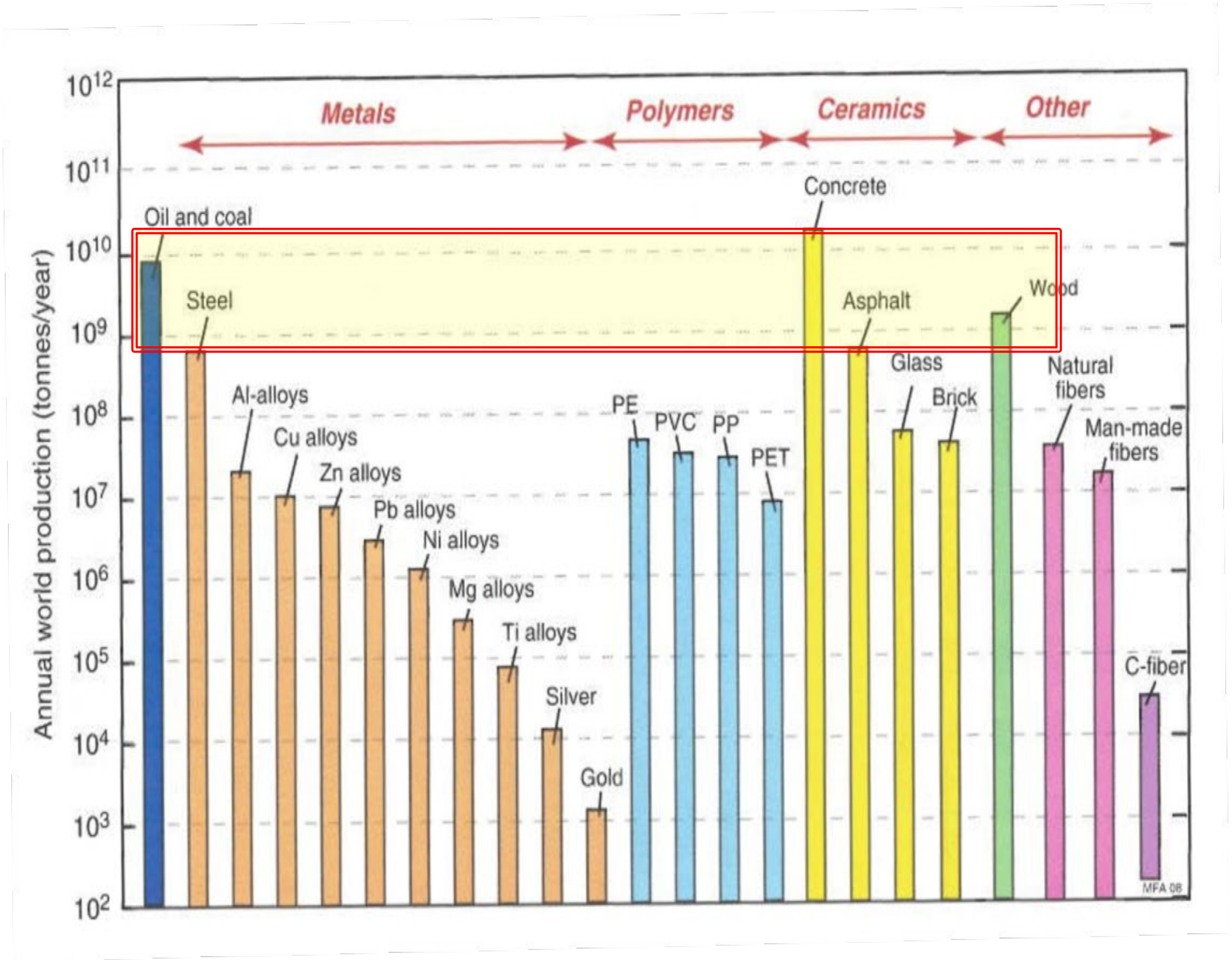
Global Cement and Concrete Association

PCA Since 1916
America's Cement Manufacturers™

Cement Association of Canada

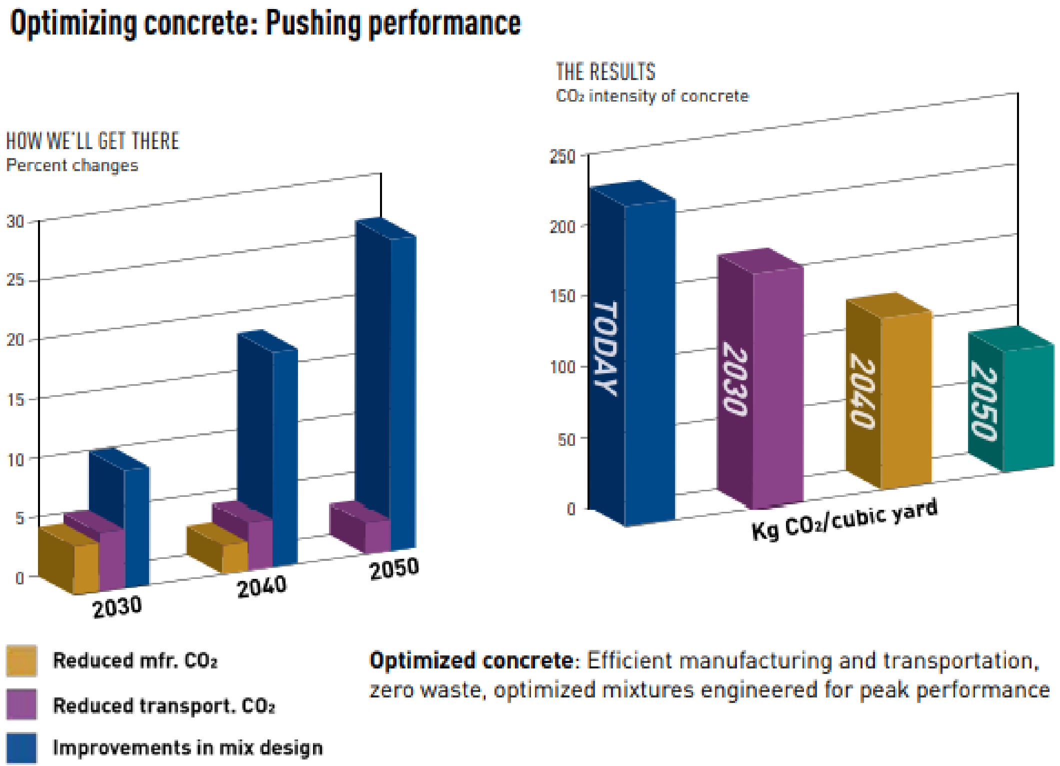


Concrete is the most used material next to water



From Ashby 2009

2050 Road maps to carbon Neutrality in concrete

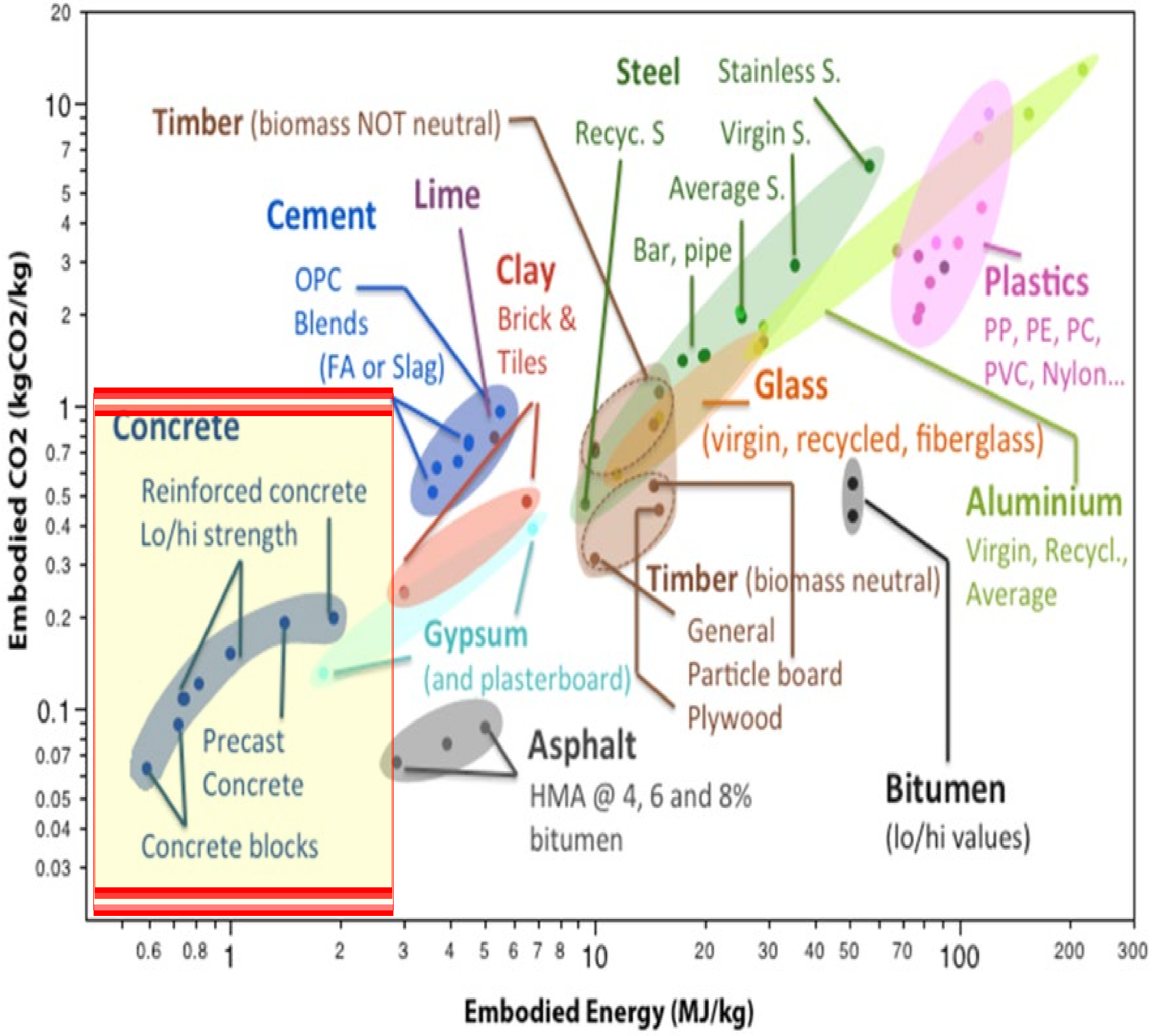


Source: PCA Roadmap to Carbon Neutrality pg 40

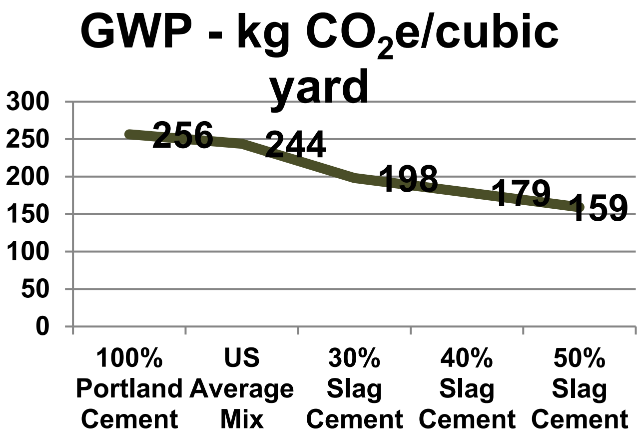
Understanding Carbon

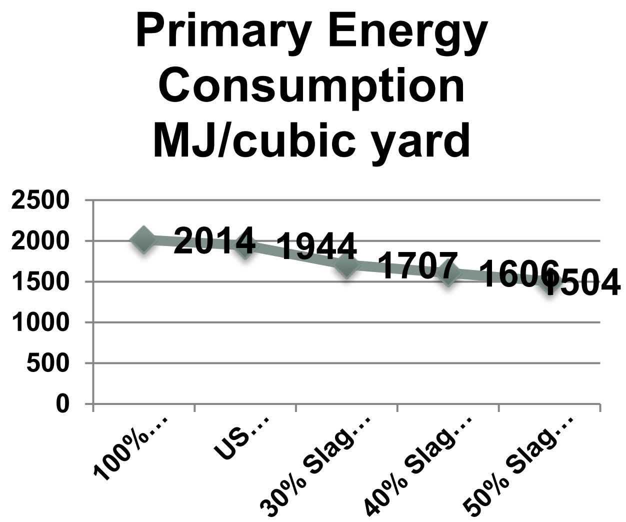
- Key Terms
  - **Operational Carbon:** Carbon load created by the use of energy to heat and power a building – 28% of total emissions
  - **Embodied Carbon*:** The greenhouse gasses that are emitted to construct structures and buildings - 11% of total emissions
  - **Carbon**: term used to indicate all greenhouse gas emissions, not just CO2
  - **(EPD) Environmental Product Declaration:** document that quantifies environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function
  - **(PCR) Product Category Rules:** documents that provide rules, requirements, and guidelines for developing an product EPD
  - **(LCA) Life Cycle Assessment:** process to evaluate, assess, and improve the environmental burdens associated with a process, product, or activity by identifying and quantifying energy and materials used and wastes released to the environment.

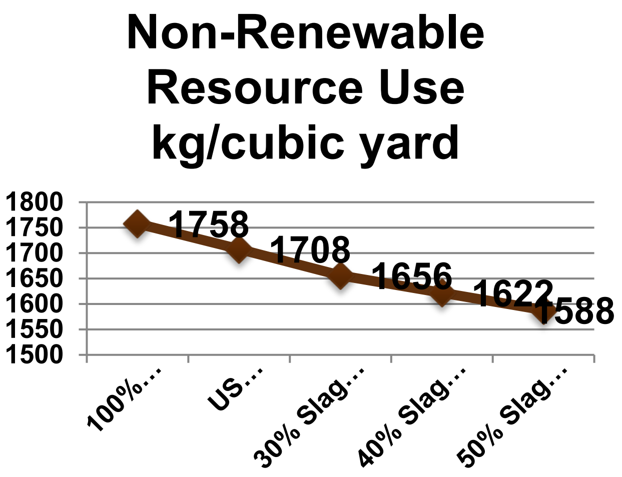
*Some consider embodied carbon to include the entire life cycle of a building, including the operational carbon. As we are discussing building materials, we will focus on **initial embodied carbon, or the impacts associated with extracting, manufacturing, and transporting materials to a jobsite.**


Embodied CO2 (kgCO2/kg)
Embodied Energy (MJ/kg)
Concrete
Reinforced concrete
Lo/hi strength
Precast
Concrete
Concrete blocks
Cement
OPC
Blends
(FA or Slag)
Lime
Clay
Brick &
Tiles
Gypsum
(and plasterboard)
Asphalt
HMA @ 4, 6 and 8%
bitumen
Timber (biomass NOT neutral)
Timber (biomass neutral)
General
Particle board
Plywood
Steel
Recyc. S
Stainless S.
Virgin S.
Average S.
Bar, pipe
Glass
(virgin, recycled, fiberglass)
Bitumen
(lo/hi values)
Plastics
PP, PE, PC,
PVC, Nylon...
Aluminium
Virgin, Recycl.,
Average

LCA Results for Concrete





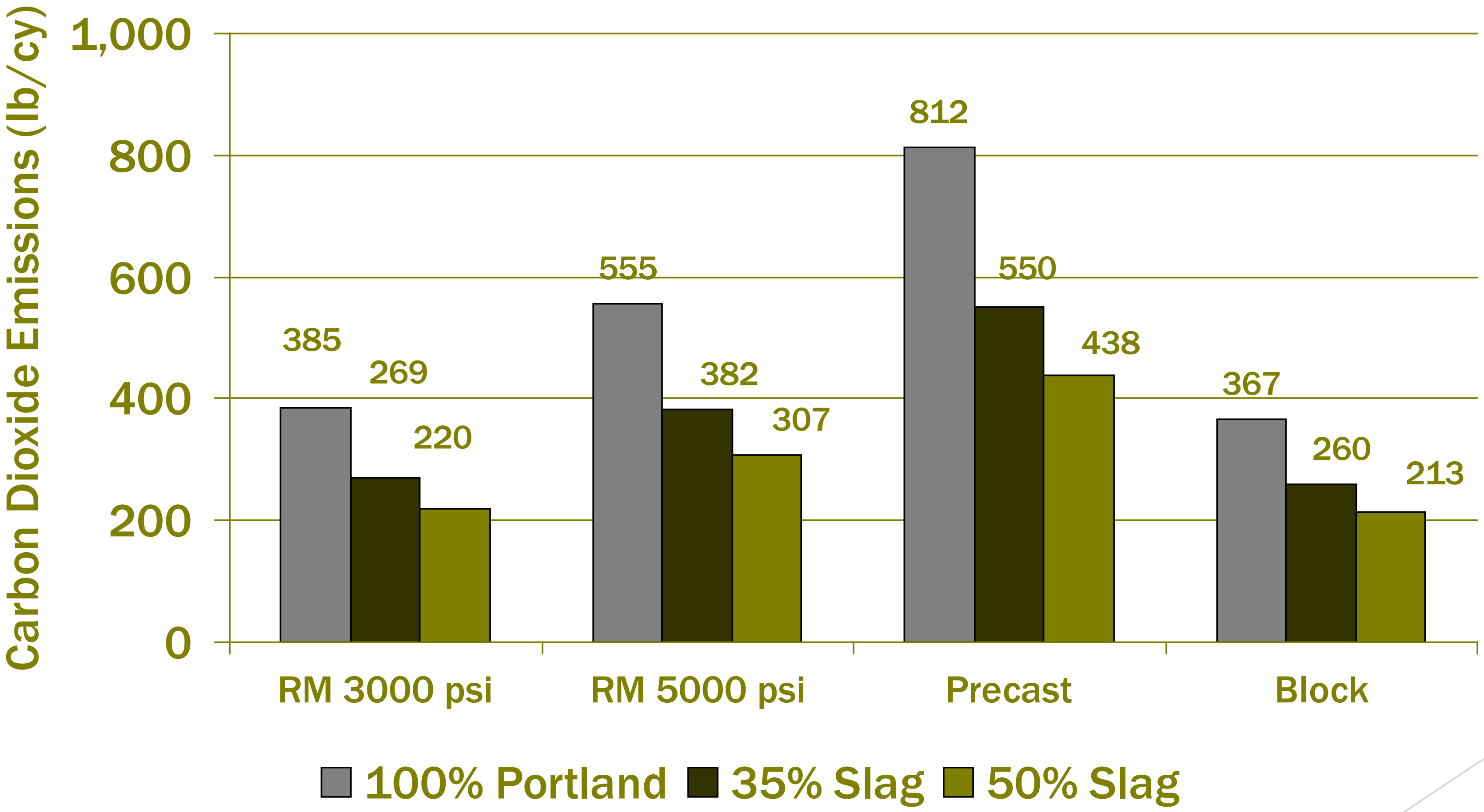


3,000 psi Mix Design

Possible savings…

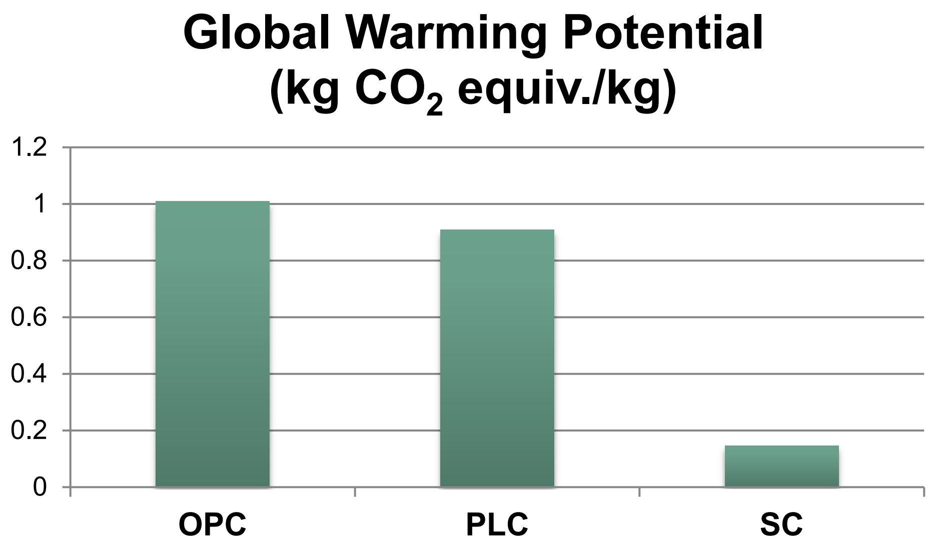
- 100 kg CO_2
- 200 kg of resources
- 500 MJ of energy

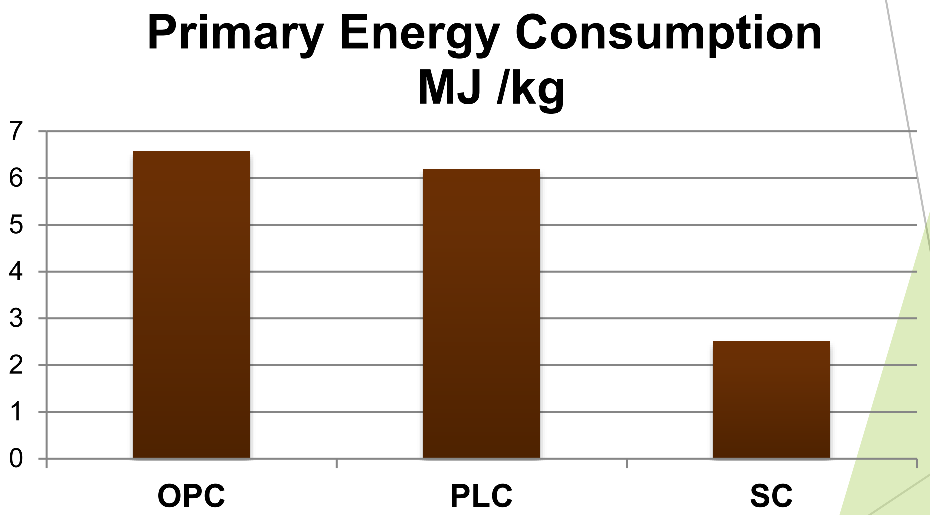
Reduced CO_2 to Produce Concrete and Concrete Products



LCA Results

Slag Cement relative to Ordinary Portland Cement & Portland Limestone Cement ....





OPC – 92% clinker, 3% limestone, 5% gypsum
PLC – 82% clinker, 13% limestone, 5% gypsum

What is PLC?

plc
portland-limestone cement
www.greenercement.org

A greener cement option

A blended cement with additional limestone content, optimized for performance

The easiest way to reduce your carbon footprint by about 10%

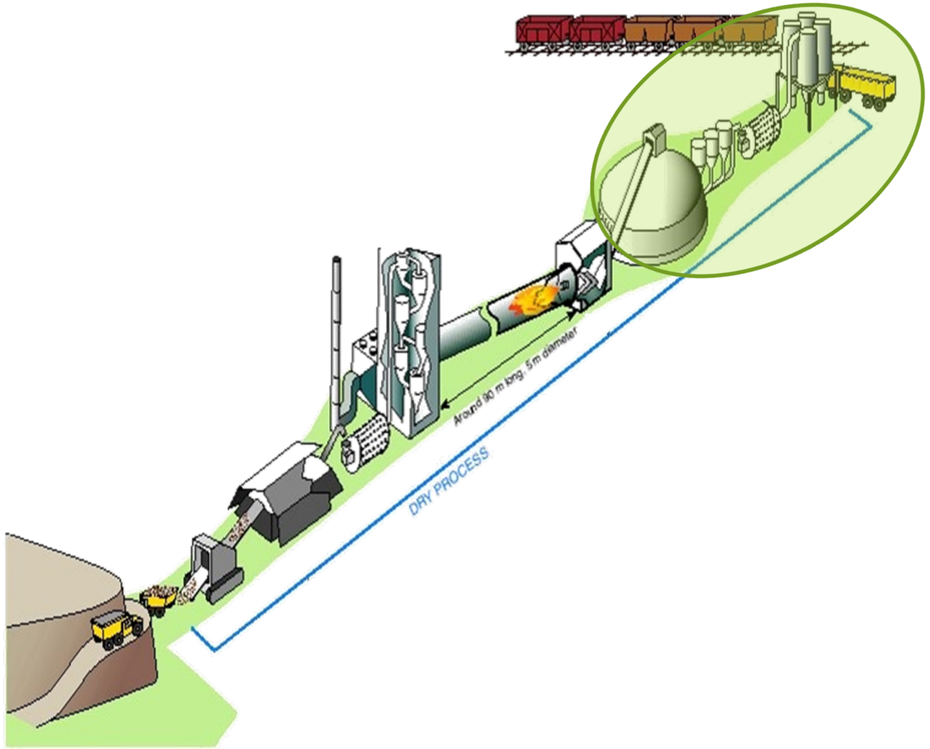
Suitable for buildings, bridges, pavements, geotechnical applications

Available throughout the U.S

www.greenercement.com for more information on:

- Specification help
- Case stud applications
- Technical papers
- Sustainable GWP tool for quick application calculations

What is PLC Cement



- What is PLC?
  - Type IL blended cement in ASTM C595/AASHTO M 240
    - 5% to 15% limestone by mass
  - Option to implement proven technology to obtain desired performance and improve sustainability of concrete

2030/2050 How do we accomplish this?

Use Smart

Do the materials you use need to be new? Are there recycled or salvaged materials that can be used instead of creating new materials?

Build Smart

Use materials, tools, and resources available to build the best product (outcome) that will also reduce the carbon impact. Life Cycle Assessment, and other modeling tools are available to compare the use of different materials

Buy Smart

Use Environmental Product Declarations as the “nutrition label” of a products environmental impact.

Sustainable Metrics

GSA U.S. General Services Administration

Buying & Selling | Real Estate | Policy & Regulations | Small Business | Travel | Shared Services

Home › About Us › Newsroom › News Releases › GSA Announces Actions to Reduce Emissions from Building Materials

GSA Announces Actions to Reduce Emissions from Building Materials

February 15, 2022

GSA releases two requests for information to gather insights on sustainable, low-emission concrete and asphalt materials

WASHINGTON — Today, as part of a governmentwide effort to strengthen American leadership on clean manufacturing, the U.S. General Services Administration (GSA) announced actions to reduce emissions from building materials. GSA released two requests for information (RFIs) to gather current marketplace insights from industry, including small businesses, on the national availability of concrete and asphalt materials with environmental product declarations, low embodied carbon or superior environmental attributes. GSA will also participate in the first ever Buy Clean Task Force established by The White House Council on Environmental Quality to find ways to harness the federal government's massive purchasing power to support low-carbon materials.

- Construction product assemblies can also qualify for IRA funding where at least 80% of the assembly's total cost or total weight comprises IRA-qualifying material such as low embodied carbon cement.

GSA IRA Limits for Low Embodied Carbon Cement - May 16, 2023 (EPD-Reported GWPs, in kilograms of carbon dioxide equivalent per metric ton - $kgCO_2e$/ t)		
Top 20% Limit	**Top 40% Limit**	**Better Than Average Limit**
751	**819**	**858**

Industry EPD's

- PCA industry Type I
  922 kgC02e/MT
- PCA industry Type IL
  844 kgC02e/MT

GSA top 20% limit

- *Detroit MI Type IT (15s)*
  668 kgCO2e/MT
- **Fleetwood PA type IS40**
  531 kgCO2e/MT
- Mississauga ON Type IL
  742 kgCO2e/MT
- Mason City IA Type IL
  687 kgCO2e/MT
- Ste. Genevieve MO Type IL
  724 kgCO2e/MT
- *Whitehall PA Type IT(25s)*
  682 kgCO2e/MT

GSA top 40% limit

- Bath ON Type IL
  771 kgCO2e/MT
- *Detroit MI Type IL*
  796 kgCO2e/MT
- Miami FL Type IL
  758 kgCO2e/MT
- Mojave CA Type IL
  815 kgCO2e/MT
- San Antonio TX Type IL
  759 kgCO2e/MT
- Union Bridge MD Type IL
  801 kgCO2e/MT

GSA better than average

- *Fleetwood PA type IS40*
  531 kgCO2e/MT
- Picton ON Type IL
  828 kgCO2e/MT
- Ragland AL Type IL
  844 kgCO2e/MT
- Redding CA Type I/II
  820 kgCO2e/MT
- San Antonio TX Type IL
  828 kgCO2e/MT
- *Whitehall PA Type IL*
  847 kgCO2e/MT

GSA above the limit

- Alpena MI Type IL
  984 kgCO2e/MT
- Charlevoix MI Type IL
  995 kgCO2e/MT
- Greencastle IN Type IL
  1023 kgCO2e/MT
- Harleyville SC Type IL
  889 kgCO2e/MT
- Leeds AL Type IL
  867 kgCO2e/MT
- Rapid City SD Type IL
  893 kgCO2e/MT

Owner's low carbon requirements

The NYS Buy Clean Concrete guidelines

Effective June 2022: The Law is intended to increase the: use and innovation of low carbon concrete in state procurement projects.

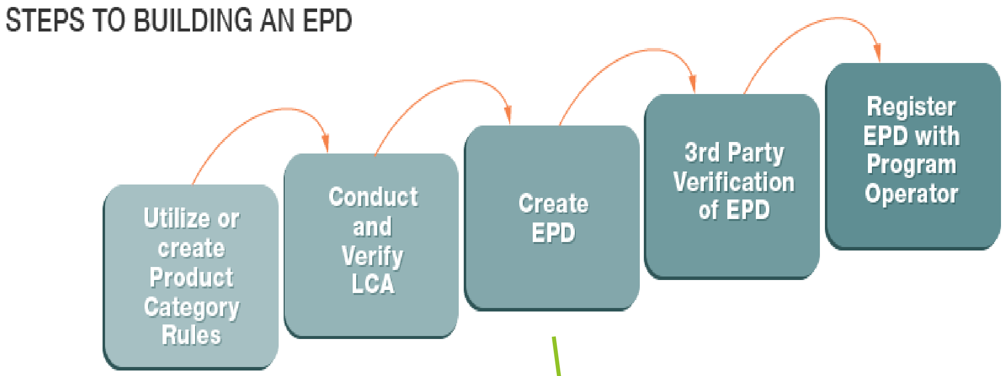
Maximum GWP (kgCO2e) Limits for NYS Buy Clean Concrete guidelines (relevant for Phase 1 and Phase 2)

Specified compressive strength (f'c in PSI)	NYS Buy Clean Concrete GWP Limits (in kilograms of carbon dioxide equivalent per cubic yard - $kgCO_2e/y^3$)
0 - 2500	275
2501 - 3000	302
3001 - 4000	360
4001 - 5000	434
5001 - 6000	458
6001 - 8000	541

2501 to 3000	410	289
3001 to 4000	456	313
4001 to 5000	503	338
5001 to 6000	531	356
6001 to 7000	594	394
7001 and higher	657	433
up to 3000 light weight	512	578
3001--4000 light weight	571	626
4001--5000 light weight	629	675

	GSA IRA Limits for Low Embodied Carbon Concrete - May 16, 2023 (EPD-Reported GWPs, in kilograms of carbon dioxide equivalent per cubic meter - $kgCO_2e/m^3$)		
Specified concrete strength class (compressive strength [f'c] in pounds per square inch [PSI])	**Top 20% Limit**	**Top 40% Limit**	**Better Than Average Limit**
≤2499	**228**	**261**	**277**
3000	**257**	**291**	**318**
4000	**284**	**326**	**352**
5000	**305**	**357**	**382**
6000	**319**	**374**	**407**
≥7200	**321**	**362**	**402**
Add 30% to these numbers for GWP limits where high early strength[1] concrete mixes are required for technical reasons.			

What is an EPD?



PCR = Guideline

EPD = Communication
“Nutrition label”

EPD “Nutrition” Label

Your Building Product

Amount per Unit

LCA IMACT MEASURES	TOTAL
Primary Energy (MJ)	12.4
Global Warming Potential (kg CO^2 eq)	0.96
Ozone Depletion (kg CFC- 11 eq)	1.80E-08
Acidification Potential (mol H^+ eq)	0.93
Eutrophication Potential (kg N^- eq)	6.43E-04
Photo-Oxidant Creation Potential (kg 03 eq)	0.121

Your Product's Ingredients: Listed Here

EPDs – ABC Process example

Data Collection LCI

ABC cement

- Operations
- Procurement
- Environment
- Adiminisration
- Logistic

Calculate core environmental impact indicators

ABC uses the **GCCA EPD Tool**

$ Results and input data are third-party verified

Athena Sustainable Materials Institute

$ Generate EPD document

ABC and the Athena Sustainable Materials Institute

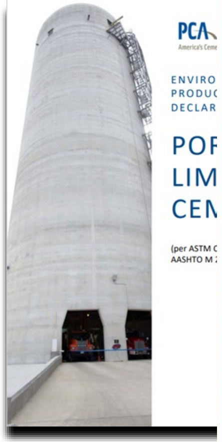
$ EPD is third-party verified

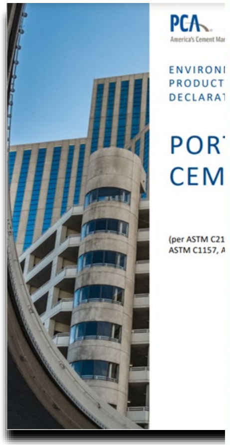
Program Operator: NRMCA

$ EPD is published

Program Operator: NRMCA

Bui





Ready Mixed Concrete LCA Calculator for Slag Cement - Version 3.0

Athena Sustainable Materials Institute

Adjust Slag Cement %

Select Mix to Adjust

Select Region

Slag Cement %

20%

Region

Great Lakes Midwest

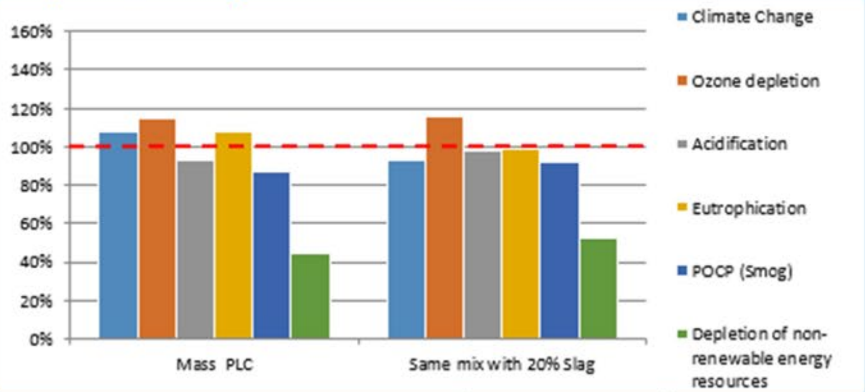
Concrete Mix

Mix ID	Mass PLC	Same mix with 20% Slag
Slag Cement (%)	#DIV/0!	20%
Strength (psi)	3000	3000
Portland Cement (lb)	0	0
Portland Limestone Cement (lb)	470	376
Masonry Cement (lb)	0	0
Slag Cement (lb)	0	94
Fly Ash (lb)	0	0
Crushed Coarse Aggregate (lb)	1750	1750
Natural Coarse Aggregate (lb)	1540	1540
Crushed Fine Aggregate (lb)	0	0
Natural Fine Aggregate (lb)	0	0
Manufactured Lightweight Aggregate (lb)	0	0
Accelerating Admixture-Chlorides (oz)	0	0
Air Entraining Admixture (oz)	0	0
Water Reducing Admixture - plasticizer (oz)	18	18
gh Range Water Reducing Admixture - superplasticizer (oz)	0	0
Water (gal)	30	30

Additional Mix Options

Crushed Demolition Concrete (lb)	0	0
Crushed Returned Concrete (lb)	0	0
Fly Ash (processed) (lb)	0	0
Mineral Fillers (lb)	0	0
Road Dust Control Chemicals (lb)	0	0
Silica Fume (no processing) (lb)	0	0
Steel Fibers (lb)	0	0
Synthetic Fibers (lb)	0	0
Accelerating Admixture-Non Chlorides (oz)	0	0
Corrosion Inhibiting Admixture (oz)	0	0
Shrinkage Reducing Admixture (oz)	0	0
Water Retarding Admixture (oz)	0	0
Waterproofing Admixture (oz)	0	0
Grease (lb)	0	0

Comparison to Strength Class Benchmark



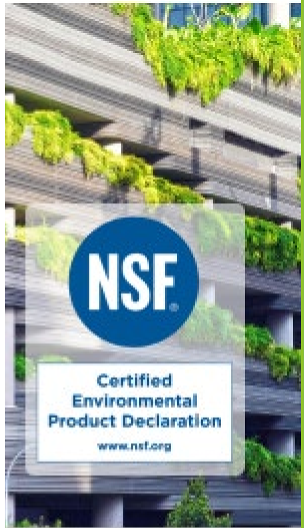
Mix ID	Mass PLC	Same mix with 20% Sla
Strength (PSI) of Relevant Benchmark	3000	3000
Climate Change	108%	93%
Ozone depletion	114%	116%
Acidification	93%	98%
Eutrophication	108%	99%
POCP (Smog)	87%	92%
Depletion of non-renewable energy resources	45%	52%

Life Cycle Assessment Results

Mix ID	Mass PLC	Same mix with 20% Sla
Climate Change (kg CO2-eq)	210.33	181.25
Ozone depletion (kg CFC-11-eq)	0.00	0.00
Acidification (kg SO2-eq)	0.57	0.60
Eutrophication (kg N-eq)	0.28	0.26
Photochemical Ozone Creation/Smog (kg O3-eq)	10.57	11.19
Abiotic Depletion Potential ADPf (MJ)	319.85	325.49
Abiotic Depletion Potential ADPe (kg Sb eq.)	0.00	0.00
Use of renewable primary energy (MJ)	38.77	35.63
Use of non-renewable primary energy (MJ)	563.35	652.10
Fresh water consumption (m3)	0.41	0.38

Introduction | Slag Substitution | Custom Mixes | Comparison to Benchmark | Impacts in Whole Building

RAGE EPD FOR



al Product Declaration

Current Industry EPD's for OPC, GUL and Slag cement

LCA Results - Type OPC/PLC/Slag one metric ton - absolute basis

Category Indicator TRACI v.2.1 Category Indicators	Unit	Total		
		OPC	PLC	Slag
Global Warming Potential (GWP)	kg CO_2eq	922	846	147.0
Acidification Potential (AP)	kg N eq.	1.75	1.64	2.0
Eutrophication Potential (EP)	kg O_2 eq.	1.02	0.94	0.33
Smog Creation Potential (POCP)	kg O_3 eq.	32.9	30.2	37.6
Ozone Depletion Potential (ODP)	kg CFC -11 eq.	2.10E-05	2.17 E-05	2.4E-05

Slag Cement LCA Results – 1 metric tonne

EPD Summary Results - One metric ton of slag cement

2015 EPD

Category Indicator	Unit	Raw Material Supply A1	Transport A2	Manufacturing A3	Total
Global warming potential	kg CO_2 eq.	4.6	57.0	85	146.6
Acidification potential	kg SO_2 eq.	0.2	1.2	0.7	2.1
Eutrophication potential	kg N eq.	0.01	0.05	0.21	0.27
Smog creation potential	kg O_3 eq.	0.4	20.2	5.8	26.5
Ozone depletion potential	kg CFC-11 eq.	4.21E-07	9.57E-06	6.9E-06	1.69E-05

Production stage EPD Results for one metric ton of Slag Cement

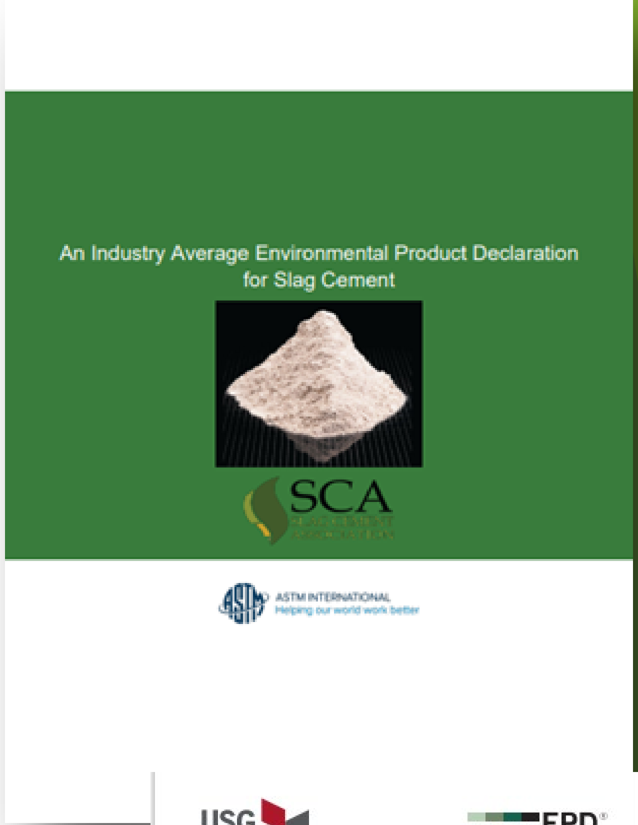
2021 EPD

Impact category and inventory indicators	Unit	A1, Extraction and upstream production	A2, Transport to factory	A3, Manufacturing	Total
Global warming potential, GWP 100[1)], AR5	kg CO_2 eq	1.8	62.7	82.6	**147.0**
Ozone depletion potential, ODP[2)]	kg CFC-11 eq	2.9E-07	1.4E-05	1.0E-05	**2.4E-05**
Smog formation potential, SFP[2)]	kg O_3 eq	0.19	33.1	4.28	**37.6**
Acidification potential, AP[2)]	kg SO_2 eq	8.7E-03	1.7	2.6E-01	**2.0**
Eutrophication potential, EP[2)]	kg N eq	2.9E-03	0.08	2.4E-01	**0.33**

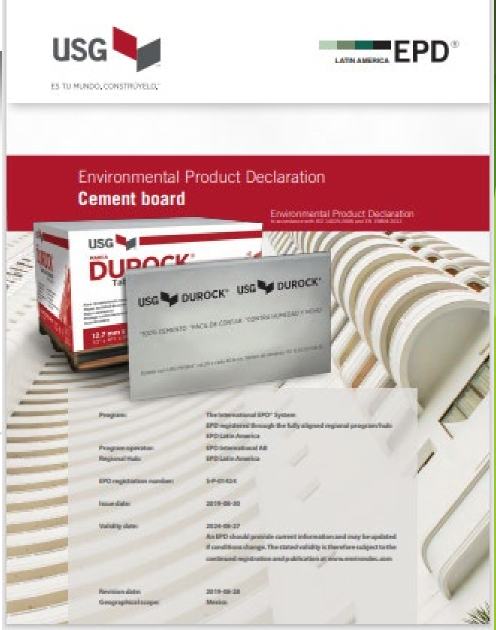
Environmental Initiatives LEED v4

MRc2: Building Product Disclosure and Optimization: Environmental Product Declaration (Possible 2 Points)

- **OPTION 1. Environmental Product Declaration (EPD) (1 Point)**
- Use at least 20 different permanently installed products sourced from at least five different manufacturers (v4.1 is now 10 epd's)
- Industry Wide EPD = ½ product, Product Specific Type III EPD = whole product (v4.1 industry 1pt)
- Product Specific Type III EPD = whole product (v4.1 TIII Specific 1.5 pts)



- Company Specific



Example of low carbon concrete using slag cement –SCA EPD tool example

- Owner: Federal Agency Building 10 story concrete frame structure
  - Project Funding: Funded by the Infrastructure Investment and Jobs Act.
    - *GSA low-emission concrete requirement for funding "GWP reduction aka lower carbon concrete"*
    - *LEED New Construction Platinum Building*
  - General Contactor specialized in low carbon concrete awarded job
    - Designer/ engineering firm likes slag cement as a lever to lower gwp
    - Concrete Contractor A: mass foundation concrete and concrete columns
      - Concrete Contractor Sub: post tension decks
    - Ready Mix Concrete Producer
      - NRMCA Industry EPD Participant
      - Cementitious Suppler A has industry EPDs for below products
        - PLC plus has product specific EPD
        - Slag Cement
      - Cementitious Suppler B
        - OPC no product disclosure

- MRC2 LEED EPD credit
  - V4 7.5/20 EPD (3 products)
    - NRMCA,SCA,PCA
    - Type III PLC
  - V4.1 13.5/10 (3 products)
    - NRMCA,SCA,PCA (1pt each)
    - Type III 1.5 pt

Cementitious solution options

- Cement Suppler A
  - Can support leed credit for supplying EPD's
  - Support durability aspects for structure
  - Support mass concrete heat of hydration
  - Materials have environmental impact numbers a
  - Ability to communicate project GWP reduction
    - SCA EPD tool Calculator for design
    - Concrete material specific EPD "information after

	Cement limits for use with prescriptive compliance methods 19.07.050.1 and 19.07.050.2	**GWP limits** for use with performance compliance methods 19.07.050.3 and 19.07.050.4
Minimum specified compressive strength f'_c, psi (5)	Maximum ordinary Portland cement content, lbs/yd^3 (1, 2, 4)	Maximum Global Warming Potential, GWP, $kg\ CO_2e/m^3$
up to 2500 (3,4)	362	260
2501 to 3000	410	289
3001 to 4000	456	313
4001 to 5000	503	338
5001 to 6000	531	356
6001 to 7000	594	394
7001 and higher	657	433
up to 3000 light weight	512	578
3001--4000 light weight	571	626
4001--5000 light weight	629	675

- Cement Suppler B
  - Project will need to use prescriptive measures
  - Project will need to find other avenues for carbon reduction and leed credits

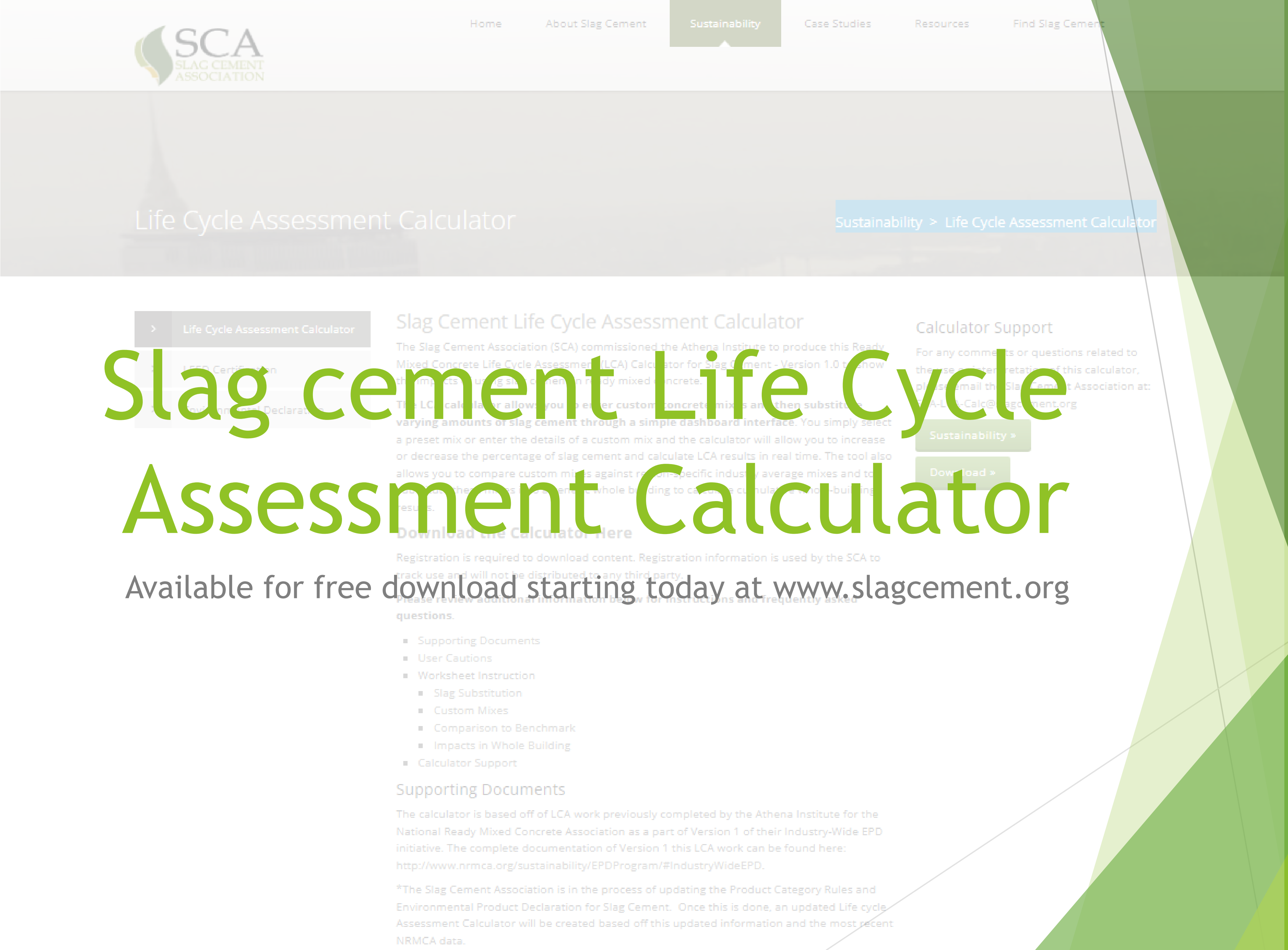
Job Site mixes

- Option A OPC
  - Prescriptive (___)
    - 410 lbs max for 3000 psi
    - 531 lbs max for 5000 psi
- Option B PLC
- Option C PLC with Slag
  - 65% slag in mass concrete
  - 35% slag in columns

	Mix 1 3000 psi mass	Mix 2 5000 psi columns and floors	
Volume	6000 yds	7000 yds	
Cementitious	470 (410)	611 (531)	
Fine Aggregate	1540	1380	
Course Aggregate	1750	1750	
Water	250 lbs	250	
WR	18 oz	24 oz	
Super P		48 oz	

Slag cement Life Cycle Assessment Calculator

Available for free download starting today at www.slagcement.org



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Ready Mixed Concrete LCA Calculator for Slag Cement - Version 3.0

Athena Sustainable Materials Institute

Adjust Slag Cement %

Select Mix to Adjust

Select Region

Slag Cement %

20%

Region

Great Lakes Midwest

Concrete Mix

Comparison to Strength Class Benchmark

Mix ID Mass PLC Same mix with 20% Slag

Climate Change

Ready Mixed Concrete LCA Calculator for Slag Cement - Version 3.0

Athena Sustainable Materials Institute

Adjust Slag Cement %

Select Mix to Adjust

Select Region

Slag Cement %

20%

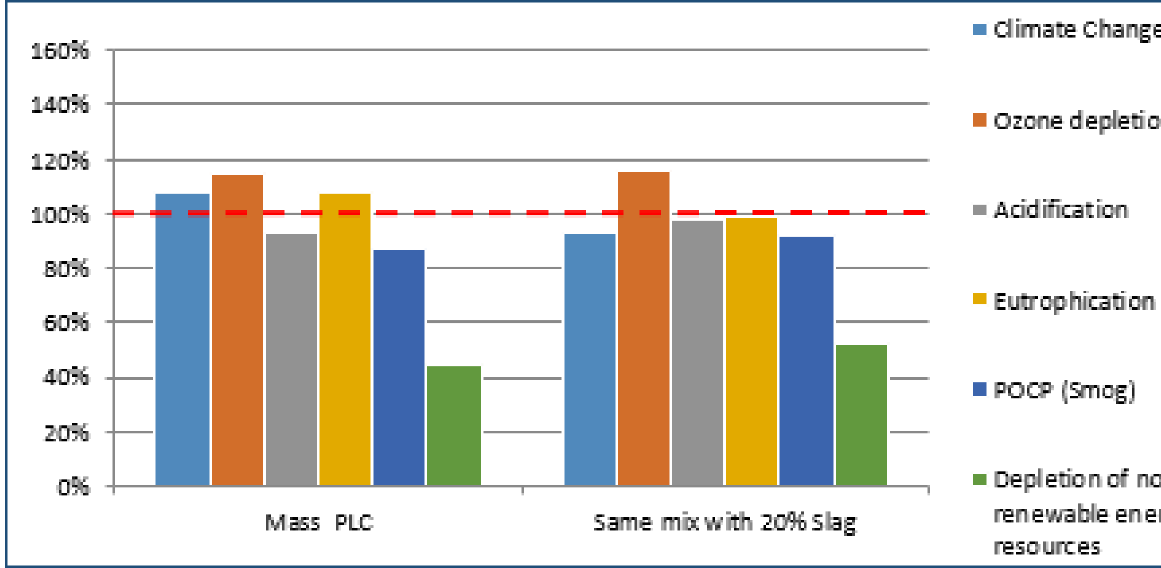
Region

Great Lakes Midwest

Concrete Mix

Mix ID	Mass PLC	Same mix with 20% Slag
Slag Cement (%)	#DIV/0!	20%
Strength (psi)	3000	3000
Portland Cement (lb)	0	0
Portland Limestone Cement (lb)	470	376
Masonry Cement (lb)	0	0
Slag Cement (lb)	0	94
Fly Ash (lb)	0	0
Crushed Coarse Aggregate (lb)	1750	1750
Natural Coarse Aggregate (lb)	1540	1540
Crushed Fine Aggregate (lb)	0	0
Natural Fine Aggregate (lb)	0	0
Manufactured Lightweight Aggregate (lb)	0	0
Accelerating Admixture-Chlorides (oz)	0	0
Air Entraining Admixture (oz)	0	0
Water Reducing Admixture - plasticizer (oz)	18	18

Comparison to Strength Class Benchmark



Mix ID | Mass PLC | Same mix with 2

Introduction | Slag Substitution | Custom Mixes | Comparison to Benchmark | Impacts in Whole Building

Using the SCA Cal Inputs

- On the customer mix tab enter custom mixes you would like to use.
- Type in Mix id
- Pick mix strength class
- Type in mix proportions
- Multiple mix classes can be entered in the custom mixes tab and mixes will be populated in the comparison to benchmark tab, impacts in whole building tab and a drop down selection in slag substitution tab.

Ready Mixed Concrete LCA Calculator for Slag Cement - Version 3.0

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Enter Data for Custom Mixes on a per yd3 basis

Concrete Mix (per yd3)

Mix ID	Mass OPC	Mass PLC	Mass slag	Floor OPC	Floor PLC	Floor slag
Strength for Benchmarking (psi)	3000	3000	3000	5000	5000	5000
Portland Cement (lb)	470	0	0	611	0	0
Portland Limestone Cement (lb)	0	470	235	0	611	458
Masonry Cement (lb)						
Slag Cement (lb)			235			153
Fly Ash (lb)						
Crushed Coarse Aggregate (lb)	1750	1750	1750	1750	1750	1750
Natural Coarse Aggregate (lb)	1540	1540	1540	1380	1380	1380
Crushed Fine Aggregate (lb)						
Natural Fine Aggregate (lb)						
Manufactured Lightweight Aggregate (lb)						
Accelerating Admixture-Chlorides (oz)						
Air Entraining Admixture (oz)						
Water Reducing Admixture - plasticizer (oz)	18	18	18	24	24	24
High Range Water Reducing Admixture - superplasticizer (oz)				48	48	48
Water (gal)	30.00	30.00	30.00	30.00	30.00	30.00

Additional Mix Options

Crushed Demolition Concrete (lb)						
Crushed Returned Concrete (lb)						
Fly Ash (processed) (lb)						
Mineral Fillers (lb)						
Road Dust Control Chemicals (lb)						
Silica Fume (no processing) (lb)						
Steel Fibers (lb)						
Synthetic Fibers (lb)						
Accelerating Admixture-Non Chlorides (oz)						

Introduction | Slag Substitution | **Custom Mixes** | Comparison to Benchmark | Impacts in Whole Building

Using the SCA Calculator Review

- The comparison to benchmark tab will show the environmental impacts compared to the NRMCA Industry EPD.

Ready Mixed Concrete LCA Calculator for Slag Cement - Version 3.0

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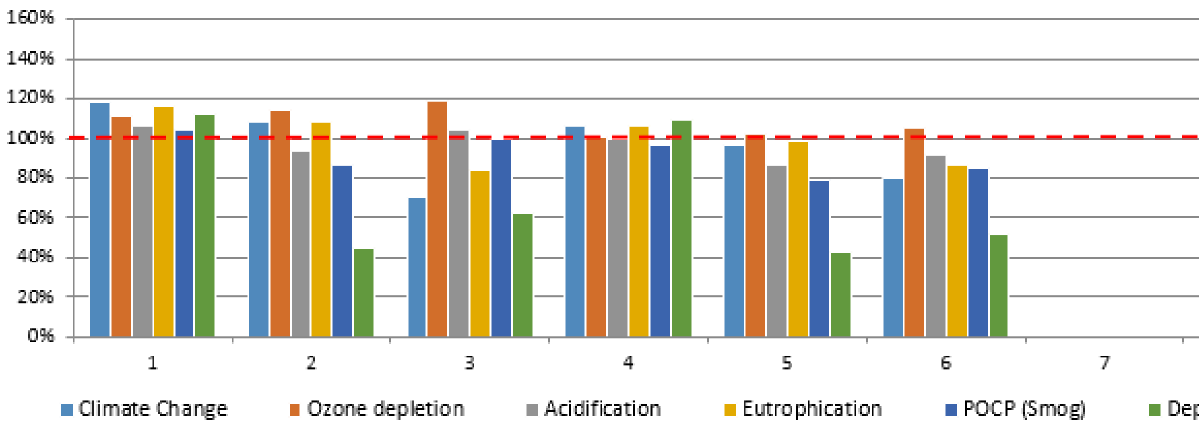
Comparison of Entered Mixes to Strength Class Benchmarks



Mix in Graph	1	2	3	4	5	6
Mix ID	Mass OPC	Mass PLC	Mass slag	Floor OPC	Floor PLC	Floor slag
Strength (PSI) of Relevant Benchmark	3000	3000	3000	5000	5000	5000
Climate Change	118%	108%	71%	106%	97%	80%
Ozone depletion	112%	114%	119%	100%	103%	105%
Acidification	106%	93%	104%	100%	87%	92%
Eutrophication	116%	108%	84%	106%	99%	87%
POCP (Smog)	105%	87%	100%	96%	79%	85%
Depletion of non-renewable energy resources	112%	45%	63%	110%	43%	51%

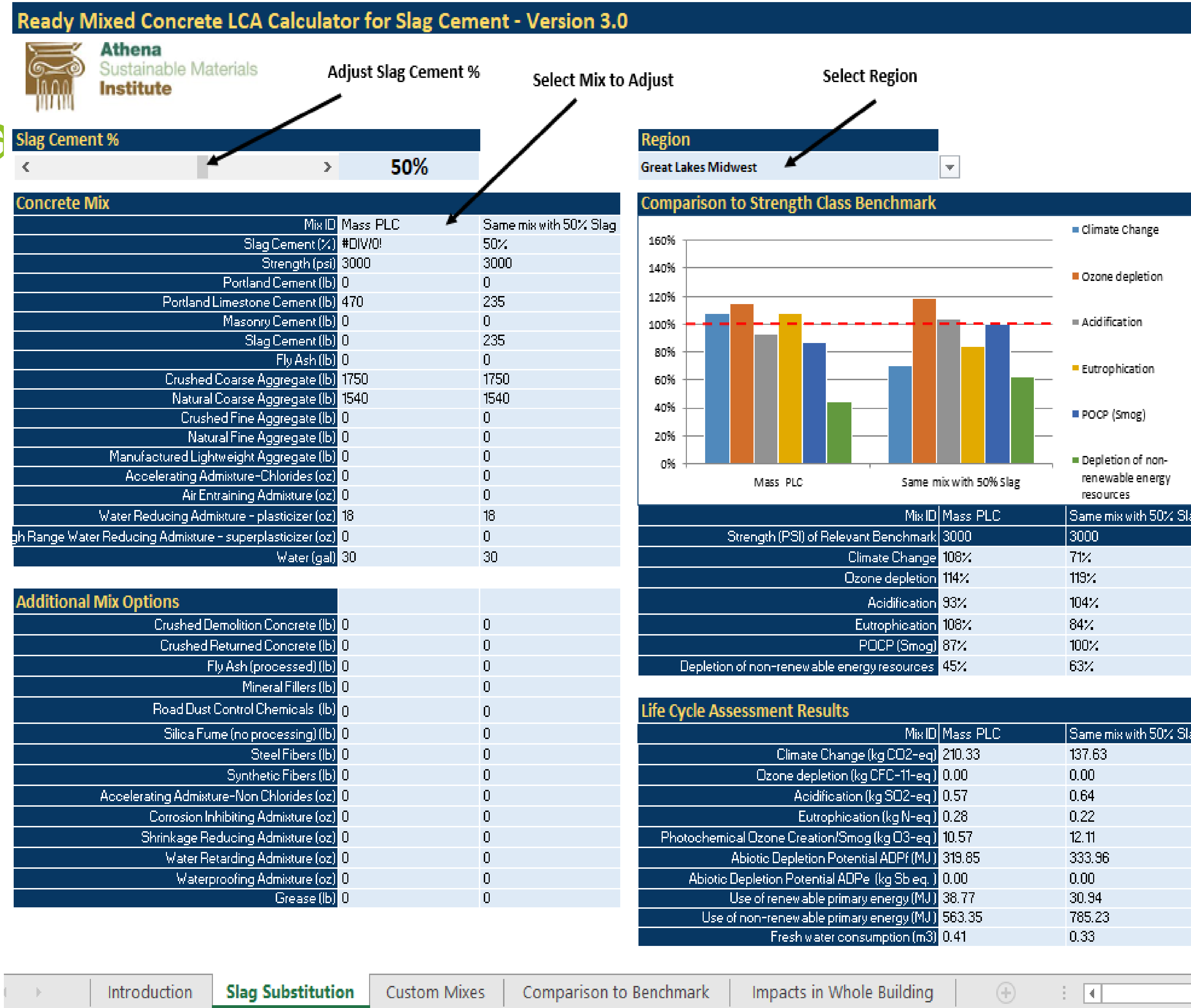
Life Cycle Assessment Results

Mix ID	Mass OPC	Mass PLC	Mass slag	Floor OPC	Floor PLC	Floor slag
Climate Change (kg CO2-eq)	230.37	210.33	137.63	295.05	269.00	221.67
Ozone depletion (kg CFC-11-eq)	6.21E-06	6.36E-06	6.60E-06	7.51E-06	7.70E-06	7.86E-06
Acidification (kg SO2-eq)	0.65	0.57	0.64	0.79	0.69	0.73
Eutrophication (kg N-eq)	0.30	0.28	0.22	0.37	0.35	0.31
Photochemical Ozone Creation/Smog (kg O3-eq)	12.71	10.57	12.11	15.18	12.40	13.40
Abiotic Depletion Potential ADPf (MJ)	373.25	319.85	333.96	514.94	445.52	454.71
Abiotic Depletion Potential ADPe (kg Sb eq.)	1.89E-04	1.88E-04	1.75E-04	3.37E-04	3.36E-04	3.28E-04
Use of renewable primary energy (MJ)	11.75	38.77	30.94	25.55	60.67	55.57
Use of non-renewable primary energy (MJ)	1,406.18	563.35	785.23	1,791.34	695.67	840.13
Fresh water consumption (m3)	0.42	0.41	0.33	0.51	0.91	0.83

Introduction | Slag Substitution | Custom Mixes | **Comparison to Benchmark** | Impacts in Wh

Using the SCA Ca Review

- The comparison to benchmark tab will show the environmental impacts compared to the NRMCA Industry EPD.
- On the Slag substitution tab select NRMCA region (column f, row 5). This will show the regional values for your area in this case the project is Michigan or Great Lakes.



Mix ID	Mass PLC	Same mix with 50% Slag
Slag Cement (%)	#DIV/0!	50%
Strength (psi)	3000	3000
Portland Cement (lb)	0	0
Portland Limestone Cement (lb)	470	235
Masonry Cement (lb)	0	0
Slag Cement (lb)	0	235
Fly Ash (lb)	0	0
Crushed Coarse Aggregate (lb)	1750	1750
Natural Coarse Aggregate (lb)	1540	1540
Crushed Fine Aggregate (lb)	0	0
Natural Fine Aggregate (lb)	0	0
Manufactured Lightweight Aggregate (lb)	0	0
Accelerating Admixture-Chlorides (oz)	0	0
Air Entraining Admixture (oz)	0	0
Water Reducing Admixture - plasticizer (oz)	18	18
gh Range Water Reducing Admixture - superplasticizer (oz)	0	0
Water (gal)	30	30

Additional Mix Options		
Crushed Demolition Concrete (lb)	0	0
Crushed Returned Concrete (lb)	0	0
Fly Ash (processed) (lb)	0	0
Mineral Fillers (lb)	0	0
Road Dust Control Chemicals (lb)	0	0
Silica Fume (no processing) (lb)	0	0
Steel Fibers (lb)	0	0
Synthetic Fibers (lb)	0	0
Accelerating Admixture-Non Chlorides (oz)	0	0
Corrosion Inhibiting Admixture (oz)	0	0
Shrinkage Reducing Admixture (oz)	0	0
Water Retarding Admixture (oz)	0	0
Waterproofing Admixture (oz)	0	0
Grease (lb)	0	0

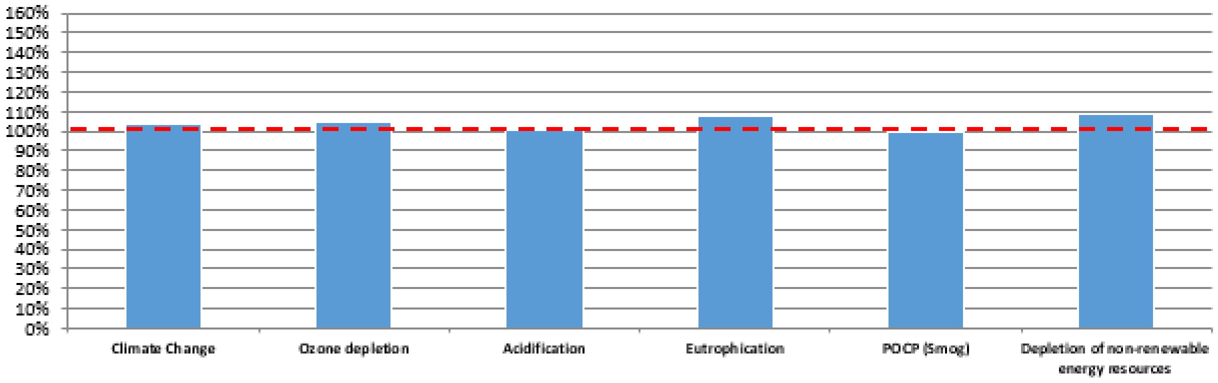
Mix ID	Mass PLC	Same mix with 50% Sl
Strength (PSI) of Relevant Benchmark	3000	3000
Climate Change	108%	71%
Ozone depletion	114%	119%
Acidification	93%	104%
Eutrophication	108%	84%
POCP (Smog)	87%	100%
Depletion of non-renewable energy resources	45%	63%

Life Cycle Assessment Results		
Mix ID	Mass PLC	Same mix with 50% Sl
Climate Change (kg CO2-eq)	210.33	137.63
Ozone depletion (kg CFC-11-eq)	0.00	0.00
Acidification (kg SO2-eq)	0.57	0.64
Eutrophication (kg N-eq)	0.28	0.22
Photochemical Ozone Creation/Smog (kg O3-eq)	10.57	12.11
Abiotic Depletion Potential ADPf (MJ)	319.85	333.96
Abiotic Depletion Potential ADPe (kg Sb eq.)	0.00	0.00
Use of renewable primary energy (MJ)	38.77	30.94
Use of non-renewable primary energy (MJ)	563.35	785.23
Fresh water consumption (m3)	0.41	0.33

Enter amounts of custom mixes used in building

Mix ID	Mass OPC	Mass PLC	Mass slag	Floor OPC	Floor PLC	Floor slag
Amount in Building (yd3)	6000	0	0	7000	0	0

Comparison of Entered Mixes to Building Constructed with Benchmark Concrete



% of Impacts of Building with Default Concrete	
Climate Change	104%
Ozone depletion	104%
Acidification	101%
Eutrophication	108%
POCP (Smog)	100%
Depletion of non-renewable energy resourc	108%

Using original 100% OPC mix val
OPC 470 lbs on mass
OPC 611 on floors

Life Cycle Assessment Results	Total Impacts		Impacts of Individual Mixes					
Mix ID	Benchmark Building	Custom Building	Mass OPC	Mass PLC	Mass slag	Floor OPC	Floor PLC	Floor slag
Climate Change (kg CO2-eq)	8,264,168.39	8,599,736.84	1,382,218.64			2,065,345.41		
Ozone depletion (kg CFC-11-eq)	9.35E-02	9.76E-02	3.72E-02			5.26E-02		
Acidification (kg SO2-eq)	38,915.95	39,136.94	3,914.53			5,543.36		
Eutrophication (kg N-eq)	5,318.12	5,717.31	1,829.87			2,617.88		
hotochemical Ozone Creation/Smog (kg O3-eq)	704,534.81	703,914.11	76,262.78			106,235.38		
letion of non-renewable energy resources (MJ)	69,356,415.02	75,200,542.96	2,239,517.25			3,604,610.69		

Introduction | Slag Substitution | Custom Mixes | Comparison to Benchmark | Impacts in Whole Building

lding

Floor slag
0

% of Impacts of Building with Default Concrete	
Climate Change	99%
Ozone depletion	95%
Acidification	99%
Eutrophication	100%
POCP (Smog)	98%
Depletion of non-renewable energy resourc	108%

Life Cycle Assessment Results	Total Impacts		Impacts of Individual Mixes					
Mix ID	Benchmark Building	Custom Building	Mass OPC	Mass PLC	Mass slag	Floor OPC	Floor PLC	Floor slag
Climate Change (kg CO2-eq)	8,264,168.39	8,211,776.50	1,230,073.62			1,829,530.08		
Ozone depletion (kg CFC-11-eq)	9.35E-02	8.91E-02	3.39E-02			4.74E-02		
Acidification (kg SO2-eq)	38,915.95	38,337.72	3,598.68			5,059.99		
Eutrophication (kg N-eq)	5,318.12	5,296.60	1,664.40			2,362.65		
hotochemical Ozone Creation/Smog (kg O3-eq)	704,534.81	688,109.96	70,006.43			96,687.58		
letion of non-renewable energy resources (MJ)	69,356,415.02	74,997,194.55	2,156,228.66			3,484,550.87		

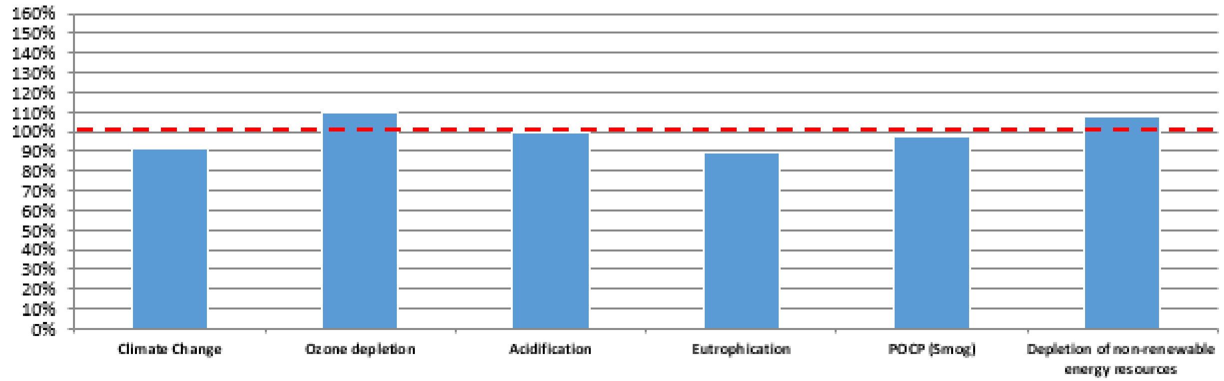
Using prescriptive values
OPC 410 lbs on mass
OPC 531 lbs on floors, columns

Introduction | Slag Substitution | Custom Mixes | Comparison to Benchmark | Impacts in Whole Building

Enter amounts of custom mixes used in building

Mix ID	Mass OPC	Mass PLC	Mass slag	Floor OPC	Floor PLC	Floor slag			
Amount in Building (yd3)	0	0	6000	0	0	7000			

Comparison of Entered Mixes to Building Constructed with Benchmark Concrete



% of Impacts of Building with Default Concrete	
Climate Change	91%
Ozone depletion	110%
Acidification	99%
Eutrophication	89%
POCP (Smog)	98%
Depletion of non-renewable energy resourc	107%

Using original PLC& Slag mix values
PLC 235 lbs/ slg 235 lbs on mass
PLC 458 lbs / slg 153 lbs on floors

Life Cycle Assessment Results	Total Impacts		Impacts of Individual Mixes							
Mix ID	Benchmark Building	Custom Building	Mass OPC	Mass PLC	Mass slag	Floor OPC	Floor PLC	Floor slag		
Climate Change (kg CO2-eq)	8,264,168.39	7,529,645.22			825,793.49			1,551,678.94		
Ozone depletion (kg CFC-11-eq)	9.35E-02	1.02E-01			3.96E-02			5.50E-02		
Acidification (kg SO2-eq)	38,915.95	38,619.09			3,827.33			5,112.71		
Eutrophication (kg N-eq)	5,318.12	4,739.95			1,326.89			2,143.51		
otochemical Ozone Creation/Smog (kg O3-eq)	704,534.81	687,858.59			72,654.52			93,788.12		
letion of non-renewable energy resources (MJ)	69,356,415.02	74,543,085.20			2,003,732.70			3,182,937.47		

% of Impacts of Building with Default Concrete	
Climate Change	99%
Ozone depletion	95%
Acidification	99%
Eutrophication	100%
POCP (Smog)	98%
Depletion of non-renewable energy resourc	108%

Introduction | Slag Sub

Mass concrete 33% GWP reduction using PLC and Slag
Floor and Columns 15% GWP reduction

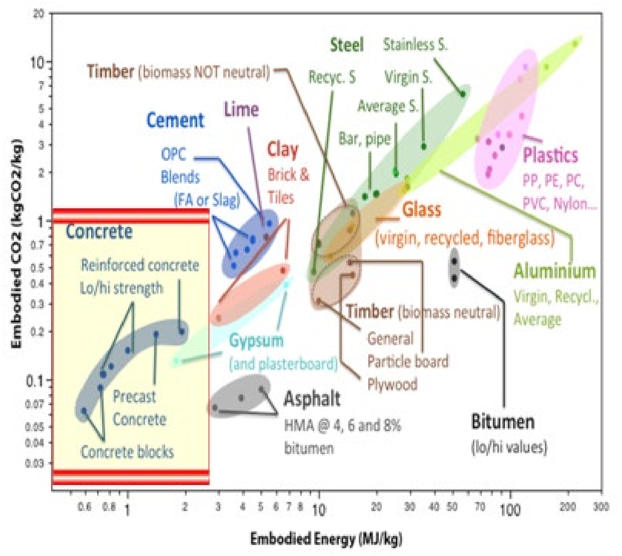
Life Cycle Assessment Results	Total Impacts		Impacts of Individual Mixes							
Mix ID	Benchmark Building	Custom Building	Mass OPC	Mass PLC	Mass slag	Floor OPC	Floor PLC	Floor slag		
Climate Change (kg CO2-eq)	8,264,168.39	8,211,776.50	1,230,073.62			1,829,530.08				
Ozone depletion (kg CFC-11-eq)	9.35E-02	8.91E-02	3.39E-02			4.74E-02				
Acidification (kg SO2-eq)	38,915.95	38,337.72	3,598.68			5,059.99				
Eutrophication (kg N-eq)	5,318.12	5,296.60	1,664.40			2,362.65				
otochemical Ozone Creation/Smog (kg O3-eq)	704,534.81	688,109.96	70,006.43			96,687.58				
letion of non-renewable energy resources (MJ)	69,356,415.02	74,997,194.55	2,156,228.66			3,484,550.87				

Using prescriptive values
OPC 410 lbs on mass
OPC 531 lbs on floors, columns

Introduction | Slag Substitution | Custom Mixes | Comparison to Benchmark | **Impacts in Whole Building**

Sustainable Benefits
“the Roadmap wrap up”

- Concrete is a lower carbon material
  - When working together designers, contractors and concrete suppliers can improve the full LCA of a project
  - Support the use of industry EPD’s and performance mixes for continuous improvement
- To get to zero emissions we need your help
  - Use of PLC and SCM like slag cement
  - Circular economy cradle to end of life solutions
  - Supporting the use of alternative fuels in clinker production to replace traditio fuels
  - Continuous use of EPD tools like
    - SCA LCA tool www.slagcement.org
    - PLC vs OPC tool www.greenercement.com
    - Adaptation use of GCCA tool www.gcca.org



Using and Improving Concrete by through the use of Slag Cement

In Summary…

Using slag cement at various replacement levels for portland cement improves:

- Consistency, workability and finishability of concrete
- Increases durability by
  - ❑ Long-term compressive and flexural strengths
  - ❑ Lowering permeability
  - ❑ Higher resistance to aggressive chemicals
- Environmental benefits
  - ❑ Recycled material
  - ❑ Less energy consumption, life cycle cost efficient
  - ❑ Pavements have greater reflectivity from lighter color

Thank You

QUESTIONS?