SUSTAINABILITY IN CONCRETE:

REDUCING ENVIRONMENTAL IMPACT THROUGH BENCHMARKING AND ALTERNATIVES

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MASON BOOTH – MASTER BUILDERS SOLUTIONS

Global Sustainability Initiatives – The Why…

Structural Engineers 2050 Challenge:

"All structural engineers shall understand, reduce and ultimately eliminate embodied carbon in their projects by 2050"

Cement/Concrete Industry & International Energy Agency:

-50% reduction in CO_2 emissions from 2006 levels by 2030 (CarbonCure)

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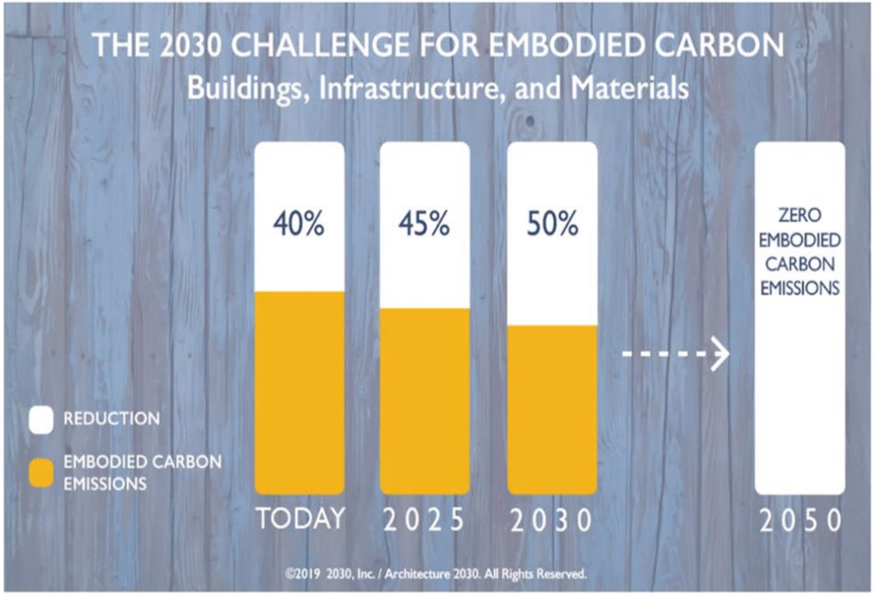
architecture 2030

Carbon Leadership Forum

LEED v4 Building Lifecycle Impact Reduction



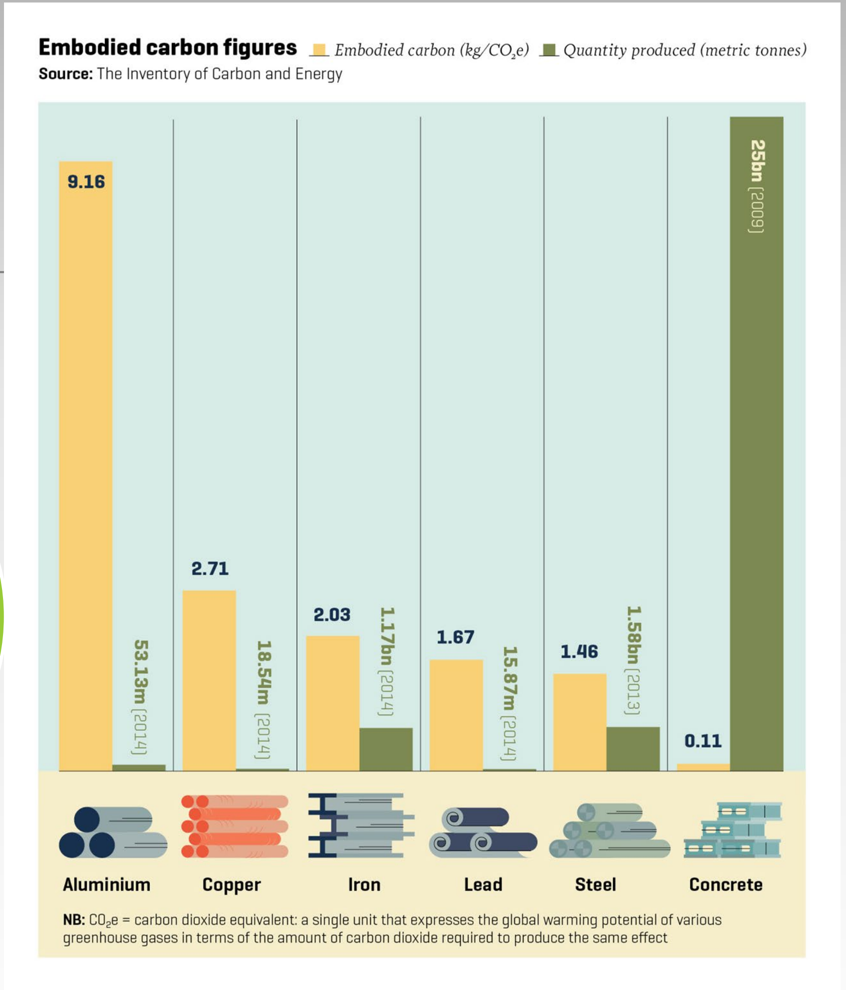
The Concrete Conundrum

Cement accounts for～8% of global CO_2 emissions

(Chatham House)

Cement accounts for 79% of CO_2 emissions related to concrete

(Jeremy Gregory)



Avenues for Reducing Environmental Impact

1 lb cement = 1.04 lb in CO2 (EPD - US Portland Cement)

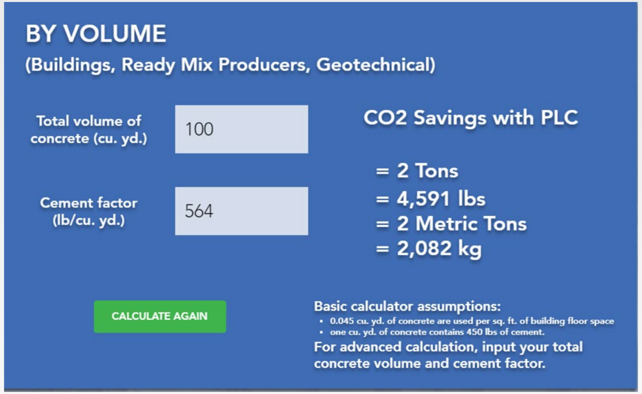
- Water
- Supplemental Cementitious Materials (SCM)
- Blended Cements
- Admixtures

Impact of Water on Cement Content

Excess Water Impacts:	Strength Development
	Durability
Common Water Addition:	Material Water Demand
	On site
Response:	Overdesign
	Liability

Strength Enhancing Admixtures	Optimization & Strength Equivalency
Water Reducers & Workability Retainers	Control w/cm and total water
Synthetic Fibers	Reducing secondary reinforcing steel & freight

Admixtures



Portland Limestone Cement

- Reduce GWP of mixes by 10%
- Equivalent Performance to Portland Cement
- 1:1 replacement of Portland Cement
- Contains 5%-15% Limestone
- Retain same amount of SCM usage
- Minor to no change on admixture dosages
- Permitted by Building Codes
- Conforms to ASTM C595, Type IL

Athena Impact Estimator

- Free tool that evaluates whole building and assemblies based on Life Cycle Assessment methodology
- Assess & Compare environmental implications of designs
- The Impact Estimator instantly provides cradle-to-grave implications in terms of:
  - **Global Warming Potential**
  - Eutrophication Potential
  - Acidification Potential
  - Fossil Fuel Consumption
  - Ozone Depletion Potential
  - Photochemical Smog Potential
  - Human Health Respiratory Effects Potential
- The Estimator takes into account the environmental impacts of:
  - Material manufacturing
  - Related transportation
  - On-site construction
  - Operational phase
  - Building type and assumed lifespan
  - Demolition and disposal
  - Maintenance and replacement effects

Replacement Solutions:
CO2
Slag
Fly Ash

Cement

1.04 kgCO2/kg

(Portland Cement Ass.)

Other

CO2
- Carbon mineralization
- Reduction of cementitious material

Slag
- 50% or higher replacement
- 0.1466 kgCO2/kg
(Slag Cement Ass.)

Fly Ash
- 30% or higher replacement
- 0.074 kgCO2/kg
(Climate Earth)

1. Class 3000 – Concrete fill
    a. Compressive strength at 28 days: 3000 psi.
    b. Minimum cement content: 423 lb/cu yd.
    c. Maximum water-cementitious ratio: 0.58
    d. Air content: Optional.
    e. Water-reducing admixture required.
    f. Synthetic fibers required in unreinforced concrete
2. Class 4000: Building interior slabs on grade, not subjected to fluid or freezing
    a. Compressive strength at 28 days: 4000 psi.
    b. Minimum cement content: 517 lb/ cu yd.
    c. Maximum water-cementitious ratio: 0.48
    d. Air content: 0 to 3 percent
    e. Mid-range water-reducing admixture required.
    f. Synthetic fibers required.
3. Class 5000WP: Concrete for below grade structures. Concrete for structures that contain or convey water or wastewater (Contains crystalline waterproofing additive).
    a. Compressive strength at 28 days: 5000 psi.
    b. Minimum cement content: 620 lb/ cu yd.
    c. Maximum water-cementitious ratio: 0.40
    d. Air content: 6 +/- percent at point of delivery
    e. High-range water-reducing admixture required.
    f. Permeability reducing admixture required.

Relating to Projects & Specifications

1. INTERPRET & INVESTIGATE
2. PROPOSE REVISIONS:

- ULTIMATE STRENGTHS
- W/CM
- MINIMUM CEMENTITIOUS

Athena Impact Tool

- Tool was developed in partnership with the Slag Cement Association
- Calculator allows for custom mixes and comparison of different designs
- We utilized it for comparison of 3 mix classes with 7 mixes in each class

Athena Sustainable Materials **Institute**

Enter Data for Custom Mixes on a per yd3 basis

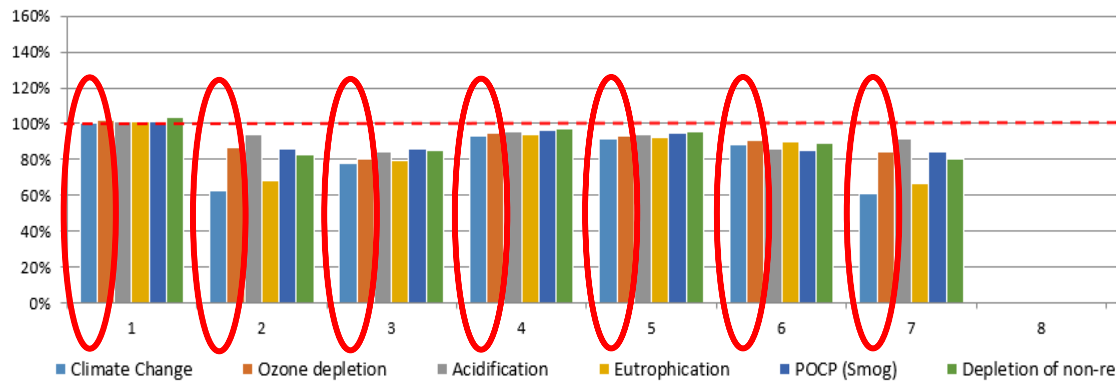
Concrete Mix (per yd3)

Mix ID	Class 5000WP	Class 5000WP -	Class 5000WP -	Class 5000WP -	Class 5000WP -	Class 5000WP -	Class 5000WP - Combo
Strength for Benchmarking (psi)	5000	5000	5000	5000	5000	5000	5000
Portland Cement (lb)	715	500	572	658	644	644	485
Slag Cement (lb)		215					209
Fly Ash (lb)			143				
Crushed Coarse Aggregate (lb)	1700	1700	1700	1700	1700	1700	1700
Natural Coarse Aggregate (lb)							
Crushed Fine Aggregate (lb)							
Natural Fine Aggregate (lb)	1250	1250	1250	1250	1250	1250	1250
Manufactured Lightweight Aggregate (lb)							
Accelerating Admixture-Chlorides (oz)							
Air Entraining Admixture (oz)	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Water Reducing Admixture - plasticizer (oz)							
High Range Water Reducing Admixture - superplasticizer (oz)	72	72	72	66	64		69
Water (gal)	31.00	31.00	31.00	31.00	31.00	31.00	31.00

Class 3000 – Options & Analysis

Athena Sustainable Materials Institute

Comparison of Entered Mixes to Strength Class Benchmarks



Mix in Graph	1	2	3	4	5	6	7
Mix ID	Class 3000 - Ber	Class 3000 - 50	Class 3000 - 20	Class 3000 - CO	Class 3000 - PLC	Class 3000 - Adr	Class 3000 - Cor
Strength (PSI) of Relevant Benchmark	3000	3000	3000	3000	3000	3000	3000
Climate Change	100%	62%	78%	93%	91%	88%	61%

Life Cycle Assessment Results

Mix ID	Class 3000 - Ber	Class 3000 - 50	Class 3000 - 20	Class 3000 - CO	Class 3000 - PLC	Class 3000 - Adr	Class 3000 - Cor
Climate Change (kg CO2-eq)	245.63	153.24	190.95	228.35	224.03	217.06	149.39

Benchmark Mix Design (per CY)

- Cement 450 lbs
- Water 31 gal
- CA 1850 lbs
- FA 1540 lbs
- Low Range Water Reducer

Option 6

- Cement 405 lbs, Slag 218 lbs
- Strength Enhancing Admix 8
- replacement
- 9% reduction
- 12% reduction

Class 4000 – Options & Analysis

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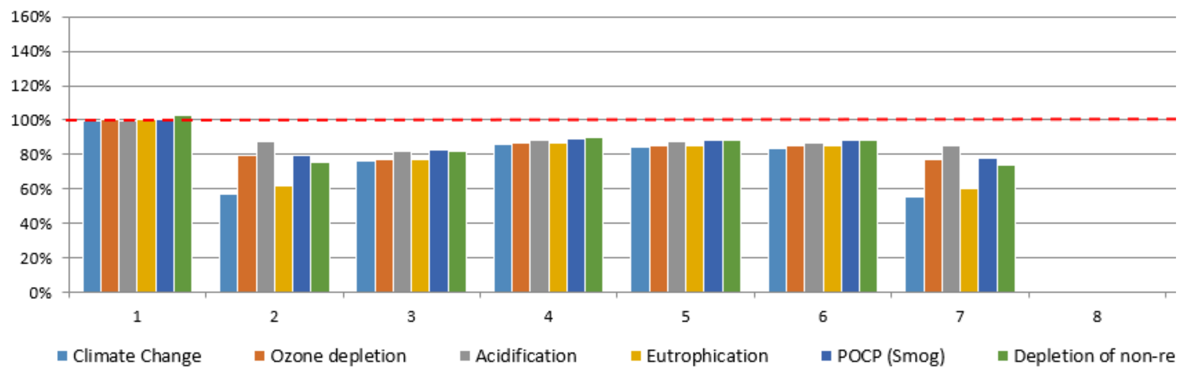
Comparison of Entered Mixes to Strength Class Benchmarks



Mix in Graph	1	2	3	4	5	6	7
Mix ID	Class 4000 - Ber	Class 4000 - 50%	Class 4000 - 20%	Class 4000 - CO	Class 4000 - PLC	Class 4000 - Adr	Class 4000 - Cor
Strength (PSI) of Relevant Benchmark	4000	4000	4000	4000	4000	4000	4000
Climate Change	100%	57%	76%	86%	84%	84%	56%

Life Cycle Assessment Results

Mix ID	Class 4000 - Ber	Class 4000 - 50%	Class 4000 - 20%	Class 4000 - CO	Class 4000 - PLC	Class 4000 - Adr	Class 4000 - Cor
Climate Change (kg CO2-eq)	299.80	171.59	228.42	257.52	252.24	252.02	167.17

Mix Options

1. Benchmark
2. 50% Slag
3. 20% Fly Ash
4. CO2
5. Portland Limestone Cement
6. Strength Enhancing Admixture
7. 50% Slag & CO2

Class 5000 – Options & Analysis

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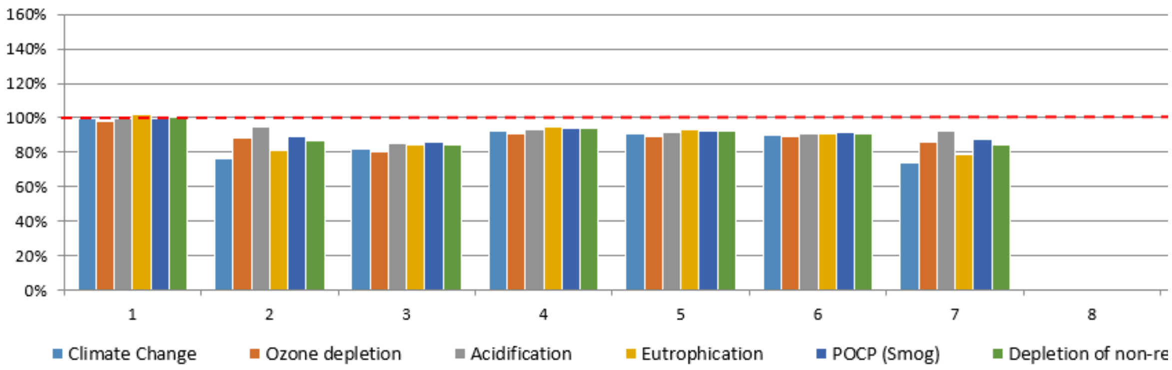
Comparison of Entered Mixes to Strength Class Benchmarks



Mix in Graph	1	2	3	4	5	6	7
Mix ID	Class 5000WP -	Class 5000WP -	Class 5000WP -	Class 5000WP -	Class 5000WP -	Class 5000WP -	Class 5000WP -
Strength (PSI) of Relevant Benchmark	5000	5000	5000	5000	5000	5000	5000
Climate Change	100%	76%	82%	92%	91%	90%	74%

Life Cycle Assessment Results

Mix ID	Class 5000WP -	Class 5000WP -	Class 5000WP -	Class 5000WP -	Class 5000WP -	Class 5000WP -	Class 5000WP -
Climate Change (kg CO2-eq)	370.84	282.82	303.10	343.29	336.52	334.44	275.12

Mix Options

1. **Benchmark**
2. **50% Slag**
3. **20% Fly Ash**
4. **CO2**
5. **Portland Limestone Cement**
6. **Strength Enhancing Admixture**
7. **50% Slag & CO2**

Considerations & Takeaways

- Several options to mitigate environmental impact while still designing mix that achieves project goals
  - Design can reduce concrete volume
- Sustainability push is coming from one direction and/or another… Legislation & Project Owners
- Special consideration should be given to what is ACTUALLY being specified when considering CO_2 emission project allowances… ex. 4000 psi post-tension mix at 24 hours is NOT a standard 4000 psi mix
- Specifications impact GWP through w/cm, min cement content, SCM limits
  - Performance specifications will have a lower impact
  - Designers and producers need to work together to utilize options available TODAY to make an impact

References

The Cement Industry, One of the World's Largest CO2 Emitters, Pledges to Cut Greenhouse Gases. (2018). *The Cement Industry, One of the World's Largest CO2 Emitters, Pledges to Cut Greenhouse Gases*. Yale E360. https://e360.yale.edu/digest/the-cement-industry-one-of-the-worlds-largest-co2-emitters-pledges-to-cut-greenhouse-gases

Chatham House: https://www.chathamhouse.org/2018/06/making-concrete-change-innovation-low-carbon-cement-and-concrete

Climate Earth EPD Generator: https://www.climateearth.com/instant-on-demand-epds/

Lemay, L. (2019, November 16). NRMCA Member Industry-Average EPD For Ready Mixed Concrete. Retrieved December 7, 2020, from https://www.nrmca.org/wp-content/uploads/2020/02/NRMCA_EPD10294.pdf

Monkman, S., PhD PEng. (2017). *Calculating Sustainability Impacts of CarbonCure Ready Mix* (Tech.). Dartmouth, NS: CarbonCure Technologies. doi:https://go.carboncure.com/rs/328-NGP-286/images/Calculating%20Sustainability%20Impacts%20of%20CarbonCure%20Ready%20Mix.pdf

PLC: Greener Cement | Home. (n.d.). PLC: Greener Cement. https://www.greenercement.com/

Portland Cement Association: https://www.cement.org/docs/default-source/sustainabilty2/pca-portland-cement-epd-062716.pdf?sfvrsn=2

Q&A: Why cement emissions matter for climate change | Carbon Brief. (2018, September 14). Carbon Brief. https://www.carbonbrief.org/qa-why-cement-emissions-matter-for-climate-change

Slag Cement Association: (https://www.slagcement.org/resources/faqs.aspx)

Climate Action Must Progress Far Faster to Achieve 1.5 C Goal. (2020, November 19). World Resources Institute. https://www.wri.org/blog/2020/11/climate-action-progress-2030-2050