Increasing Concrete Sustainability while Improving Durability

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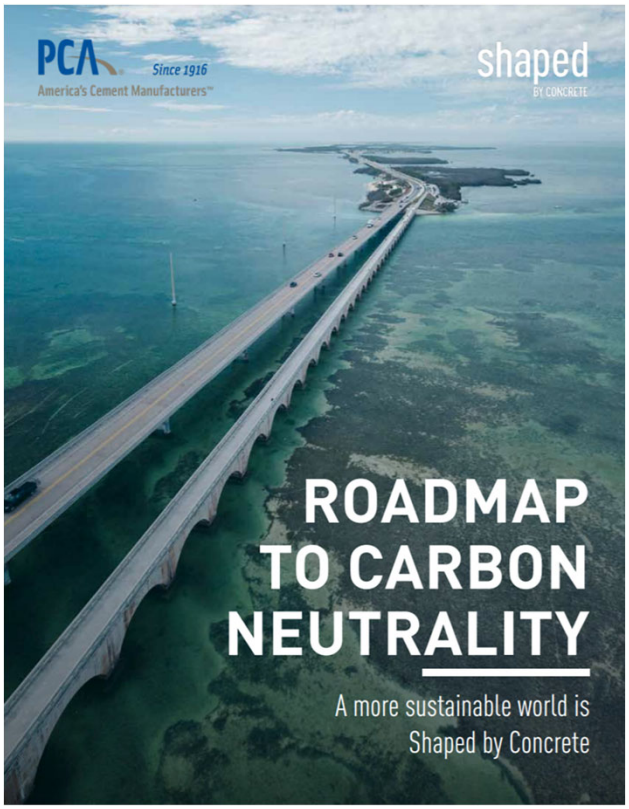
CO/WY Chapter – American Concrete Pavement Association (ACPA)

ACPA COLORADO/WYOMING CHAPTER

Count on CONCRETE

Stages of Opportunities for Reducing GHG Emissions & Increasing Sustainability

- Before Construction
- During Construction
- After Construction



ShapedByConcrete.com

CLINKER
Key chemically reactive ingredient

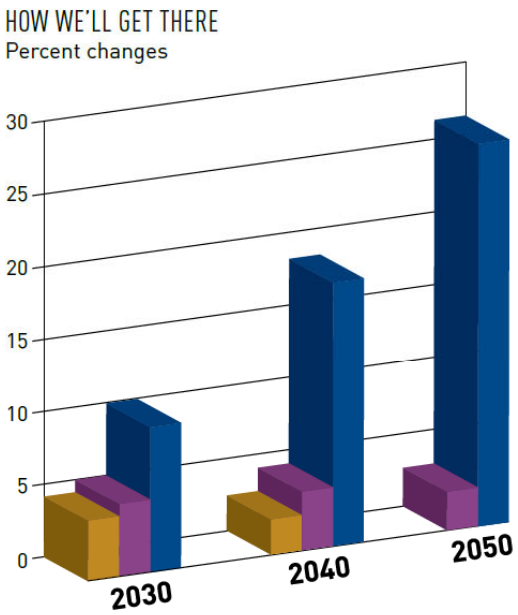
CEMENT
The binder

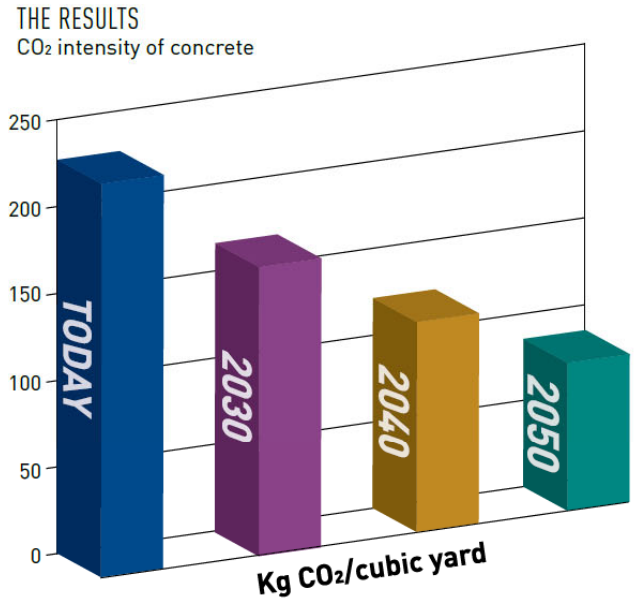
CONCRETE
Critically useful material to society

CONSTRUCTION
Service life / use phase impacts

CARBONATION
Concrete is a CO_2 sink

Optimizing Concrete: Pushing Performance

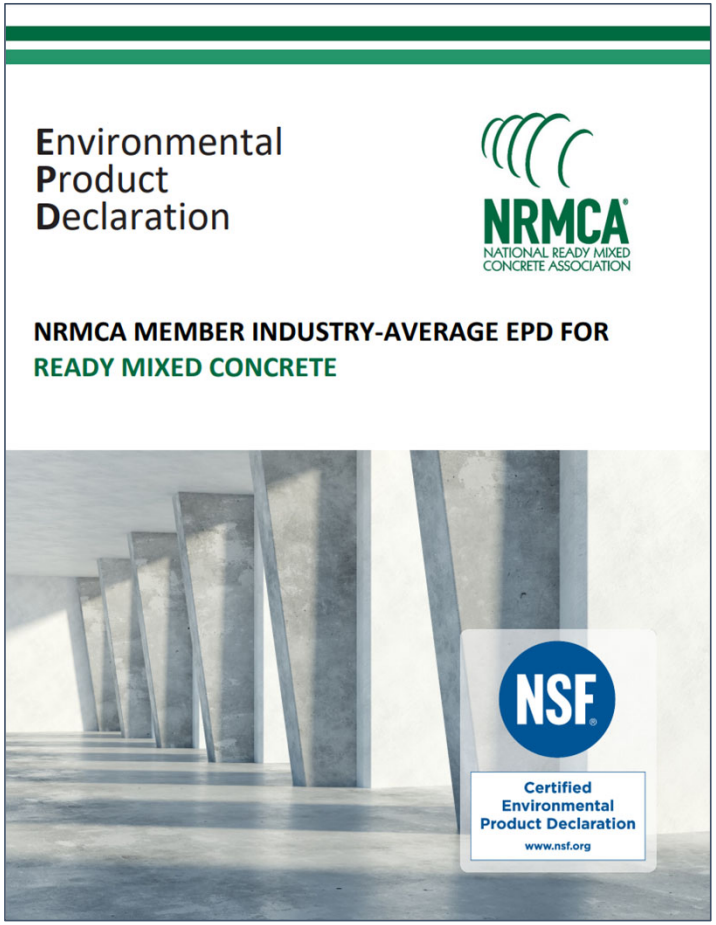


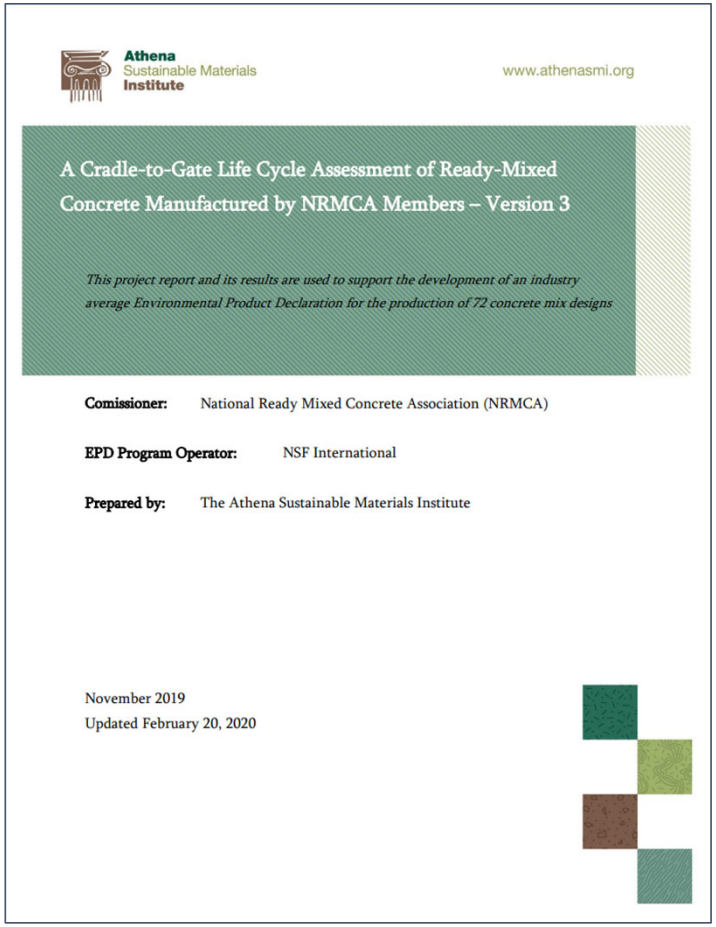


Optimized concrete: Efficient manufacturing and transportation, zero waste, optimized mixtures engineered for peak performance

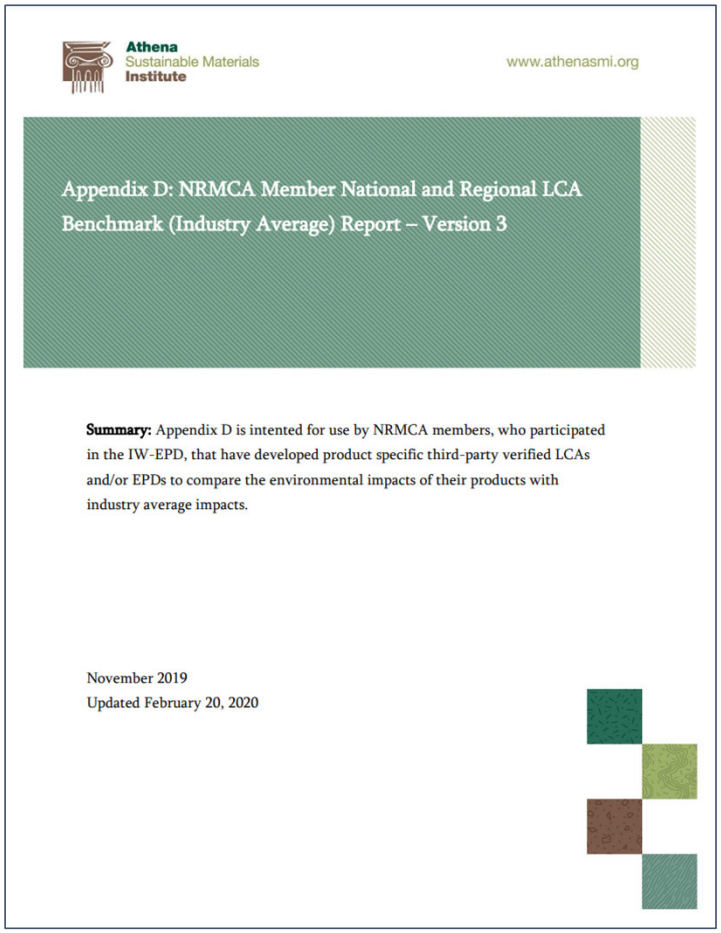
Source: PCA's Roadmap to Carbon Neutrality

NRMCA Industry-Wide (Average) EPD





NRMCA Regional Benchmarks Report



Athena Sustainable Materials Institute

www.athenasmi.org

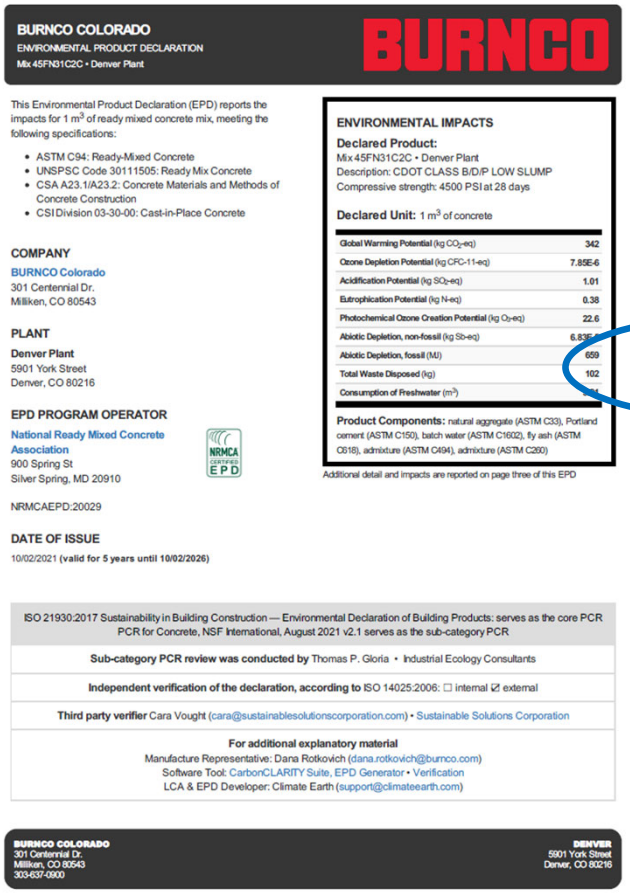
Appendix D: NRMCA Member National and Regional LCA Benchmark (Industry Average) Report – Version 3

Summary: Appendix D is intented for use by NRMCA members, who participated in the IW-EPD, that have developed product specific third-party verified LCAs and/or EPDs to compare the environmental impacts of their products with industry average impacts.

November 2019
Updated February 20, 2020

Figure D1-NRMCA Regions

Example EPDs for CDOT Class P (Paving) Concrete



BURNCO COLORADO
ENVIRONMENTAL PRODUCT DECLARATION
Mix 45FN31C2C • Denver Plant

BURNCO

This Environmental Product Declaration (EPD) reports the impacts for 1 m^3 of ready mixed concrete mix, meeting the following specifications:

- ASTM C94: Ready-Mixed Concrete
- UNSPSC Code 30111505: Ready Mix Concrete
- CSA A23.1/A23.2: Concrete Materials and Methods of Concrete Construction
- CSI Division 03-30-00: Cast-in-Place Concrete

COMPANY
BURNCO Colorado
301 Centennial Dr.
Milliken, CO 80543

PLANT
Denver Plant
5901 York Street
Denver, CO 80216

EPD PROGRAM OPERATOR
National Ready Mixed Concrete Association
900 Spring St
Silver Spring, MD 20910

NRMCAEPD:20029

DATE OF ISSUE
10/02/2021 **(valid for 5 years until 10/02/2026)**

ENVIRONMENTAL IMPACTS

Declared Product:
Mix 45FN31C2C • Denver Plant
Description: CDOT CLASS B/D/P LOW SLUMP
Compressive strength: 4500 PSI at 28 days

Declared Unit: 1 m^3 of concrete

Global Warming Potential (kg CO_2-eq)	342
Ozone Depletion Potential (kg CFC-11-eq)	7.85E-6
Acidification Potential (kg SO_2-eq)	1.01
Eutrophication Potential (kg N-eq)	0.38
Photochemical Ozone Creation Potential (kg O_3-eq)	22.6
Abiotic Depletion, non-fossil (kg Sb-eq)	6.83E-5
Abiotic Depletion, fossil (MJ)	659
Total Waste Disposed (kg)	102
Consumption of Freshwater (m^3)	0.74

Product Components: natural aggregate (ASTM C33), Portland cement (ASTM C150), batch water (ASTM C1602), fly ash (ASTM C618), admixture (ASTM C494), admixture (ASTM C260)

Additional detail and impacts are reported on page three of this EPD

ISO 21930:2017 Sustainability in Building Construction — Environmental Declaration of Building Products: serves as the core PCR
PCR for Concrete, NSF International, August 2021 v2.1 serves as the sub-category PCR

Sub-category PCR review was conducted by Thomas P. Gloria • Industrial Ecology Consultants

Independent verification of the declaration, according to ISO 14025:2006: ☐ internal ☑ external

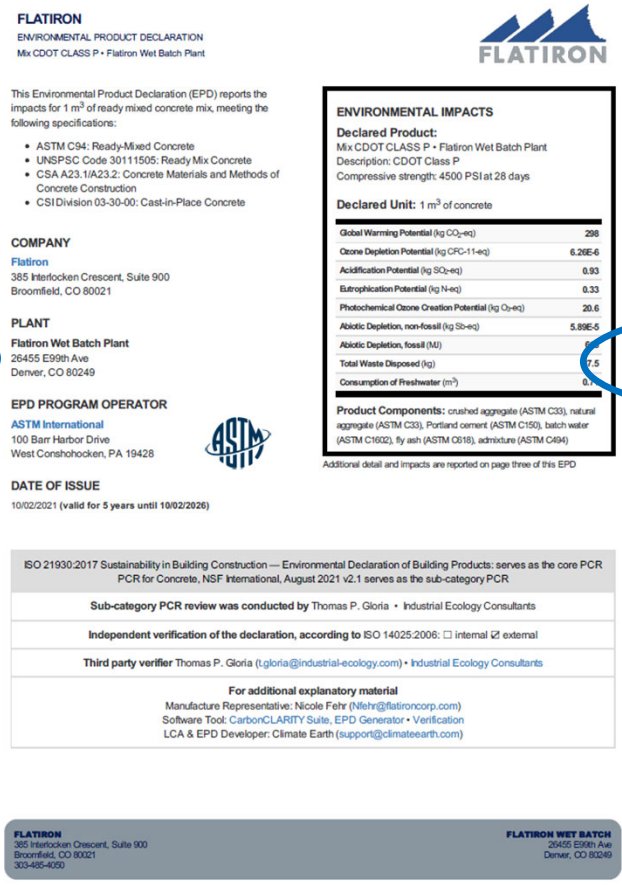
Third party verifier Cara Vought (cara@sustainablesolutionscorporation.com) • Sustainable Solutions Corporation

For additional explanatory material
Manufacture Representative: Dana Rotkovich (dana.rotkovich@burnco.com)
Software Tool: CarbonCLARITY Suite, EPD Generator • Verification
LCA & EPD Developer: Climate Earth (support@climateearth.com)

BURNCO COLORADO
301 Centennial Dr.
Milliken, CO 80543
303-637-0900

DENVER
5901 York Street
Denver, CO 80216

- CDOT B/D/P
- Impacts for 1 m^3
- 4,500 psi @ 28 days
- GWP: 342 kg CO_2-eq
- EPD Program: NRMCA
- 3rd party verifier: Sustainable Solutions Corp.
- LCA & EPD Developer: Climate Earth



FLATIRON
ENVIRONMENTAL PRODUCT DECLARATION
Mix CDOT CLASS P • Flatiron Wet Batch Plant

FLATIRON

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- ASTM C94: Ready-Mixed Concrete
- UNSPSC Code 30111505: Ready Mix Concrete
- CSA A23.1/A23.2: Concrete Materials and Methods of Concrete Construction
- CSI Division 03-30-00: Cast-in-Place Concrete

COMPANY
Flatiron
385 Interlocken Crescent, Suite 900
Broomfield, CO 80021

PLANT
Flatiron Wet Batch Plant
26455 E99th Ave
Denver, CO 80249

EPD PROGRAM OPERATOR
ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428

DATE OF ISSUE
10/02/2021 **(valid for 5 years until 10/02/2026)**

ENVIRONMENTAL IMPACTS

Declared Product:
Mix CDOT CLASS P • Flatiron Wet Batch Plant
Description: CDOT Class P
Compressive strength: 4500 PSI at 28 days

Declared Unit: 1 m^3 of concrete

Global Warming Potential (kg CO_2-eq)	298
Ozone Depletion Potential (kg CFC-11-eq)	6.26E-6
Acidification Potential (kg SO_2-eq)	0.93
Eutrophication Potential (kg N-eq)	0.33
Photochemical Ozone Creation Potential (kg O_3-eq)	20.6
Abiotic Depletion, non-fossil (kg Sb-eq)	5.89E-5
Abiotic Depletion, fossil (MJ)	5[illegible]
Total Waste Disposed (kg)	7.5
Consumption of Freshwater (m^3)	0.7[illegible]

Product Components: crushed aggregate (ASTM C33), natural aggregate (ASTM C33), Portland cement (ASTM C150), batch water (ASTM C1602), fly ash (ASTM C618), admixture (ASTM C494)

Additional detail and impacts are reported on page three of this EPD

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Third party verifier Thomas P. Gloria (t.gloria@industrial-ecology.com) • Industrial Ecology Consultants

For additional explanatory material
Manufacture Representative: Nicole Fehr (Nfehr@flatironcorp.com)
Software Tool: CarbonCLARITY Suite, EPD Generator • Verification
LCA & EPD Developer: Climate Earth (support@climateearth.com)

FLATIRON
385 Interlocken Crescent, Suite 900
Broomfield, CO 80021
303-485-4050

FLATIRON WET BATCH
26455 E99th Ave
Denver, CO 80249

- CDOT P
- Impacts for 1 m^3
- 4,500 psi @ 28 days
- GWP: 298 kg CO_2-eq
- EPD Program: ASTM
- 3rd party verifier: Industrial Ecology Consult.
- LCA & EPD Developer: Climate Earth

Reducing Emissions Before & During Construction

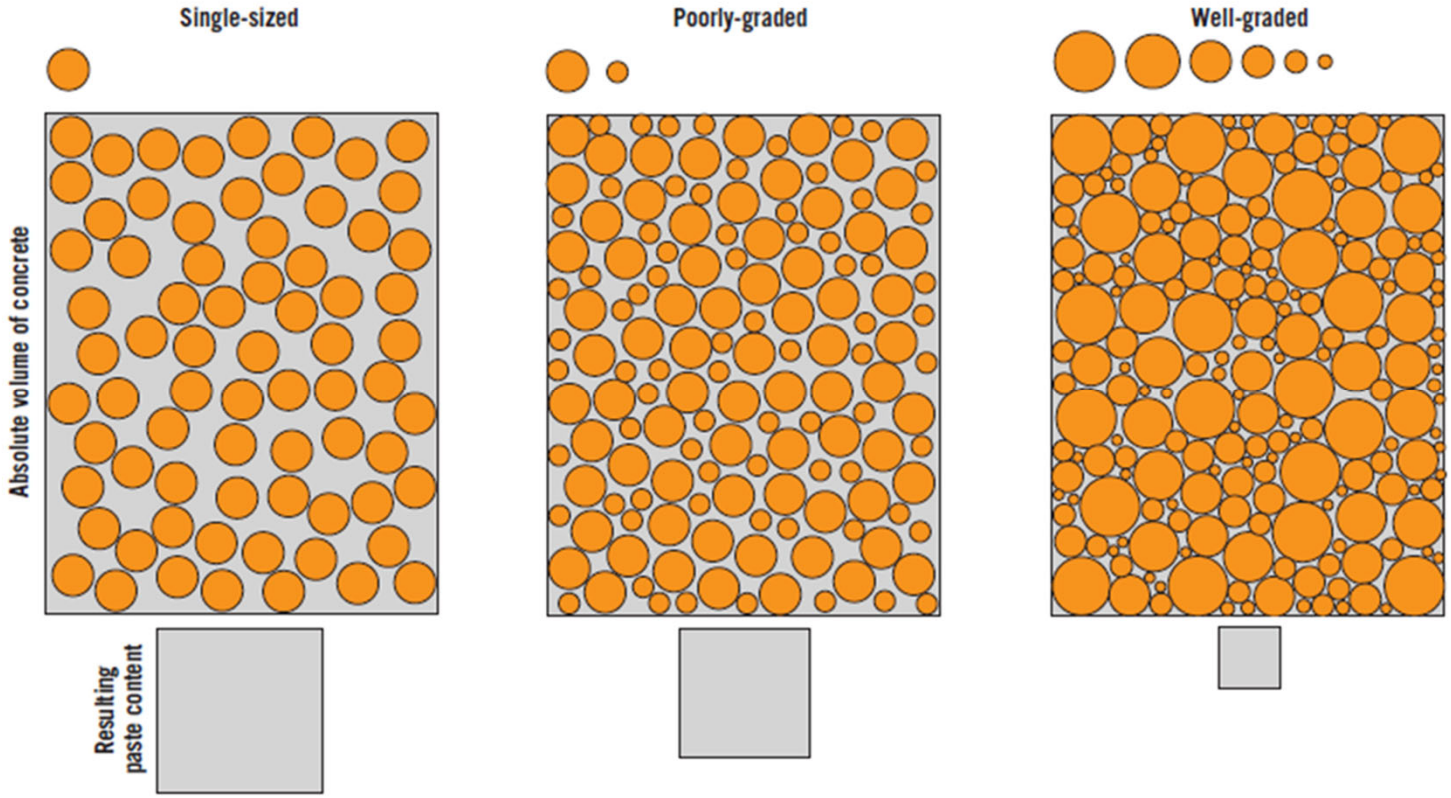
- Pavement Design – CDOT use of Pavement ME
- Materials Selection and Mixture Design Specifications
  - Aggregates
    - Multiple gradations
    - Recycled concrete
  - Cementitious Materials
    - Portland Limestone Cement (PLC), or Type IL
    - Supplementary cementitious materials

Most common target of discussion based on cement's reputation as a large producer of greenhouse gas emissions

Concrete Mix Specifications: Use Performance Engineered Mixtures (PEM)

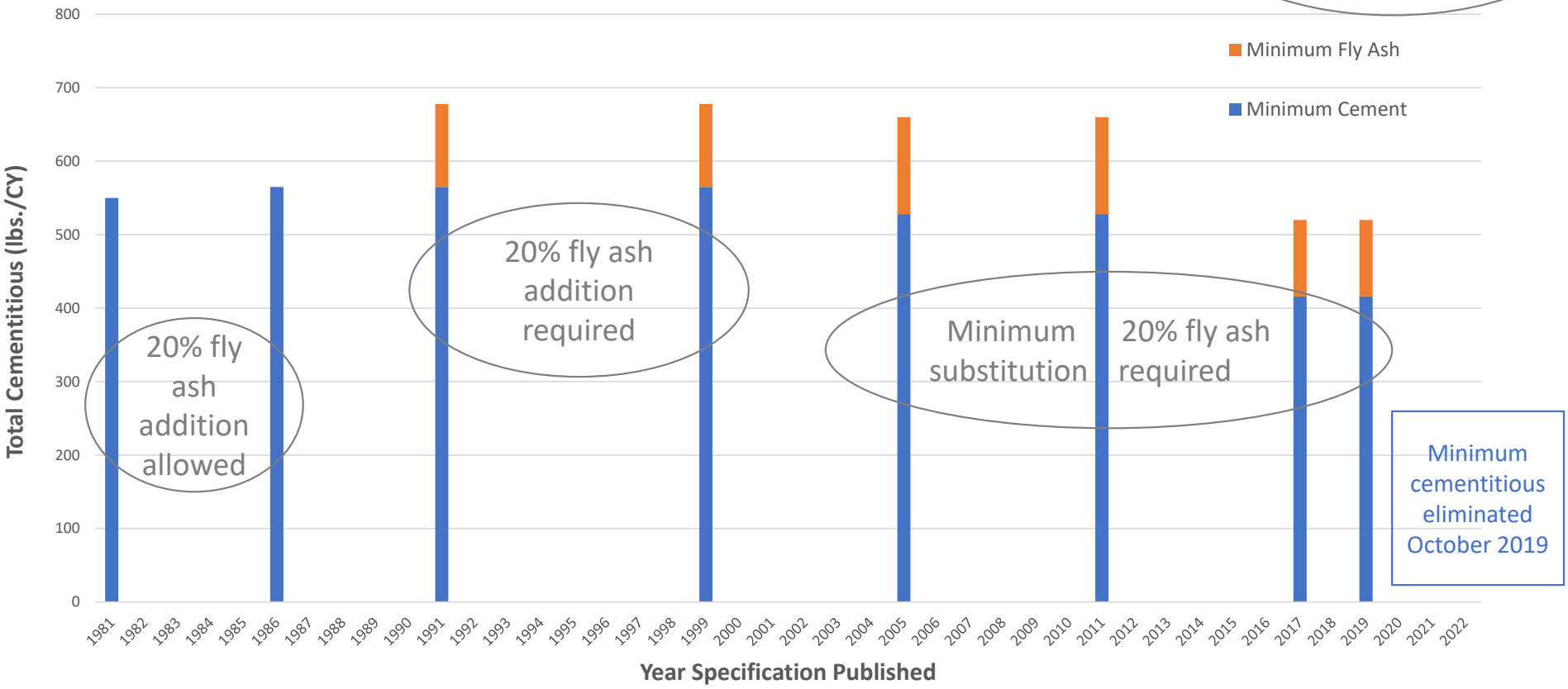
- Optimized gradations – reduces paste content (and cement)
- Recycled concrete
  - Aggregate in new concrete
  - Base material
- Allow for Portland Limestone Cement (PLC) – aka Type IL
- Require use of supplementary cementitious materials
  - Fly ash – byproduct of coal fired power production
  - Slag cement – byproduct of steel production
- Include permeability testing

Optimized Gradations



CDOT Concrete Pavement Minimum Cementitious Contents

25%+ reduction in min. cement content from 1999 to 2017

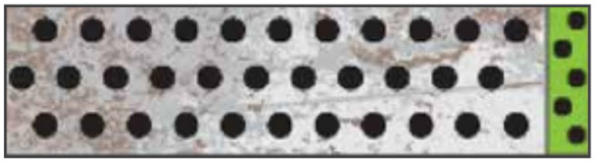


Portland Limestone Cement (PLC) – AKA Type IL

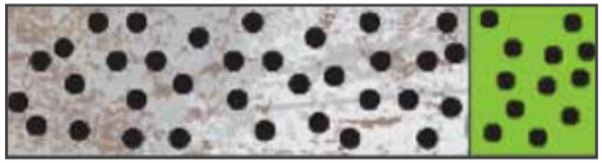
Blended cement with higher limestone content & average reduction in carbon footprint of 10%

www.greenercement.com

Portland cement can contain up to 5% limestone along with the clinker



Portland-limestone cement can contain from 5% to 15% limestone along with the clinker.



If all cement used in the U.S. in 2019 had been converted to PLC (Type IL), it would have reduced CO_2 emissions by 8.1 million metric tons, which the U.S. EPA says is the equivalent of taking 1.75 million cars off the road for an entire year.

Why Portland Limestone Cement (PLC)?

- Producing PLC reduces amount of cement clinker needed per ton
  - Reduces carbon footprint of cement/concrete
  - Every 10 tons of PLC produced reduces CO_2 emissions by approximately 1 ton compared to OPC
  - Reduces the amount of energy required per ton of cement
- Producing PLC increases cement plant capacity
  - Varies from plant to plant depending on clinker capacity vs. mill capacity
- Designed to perform the same as Ordinary Portland Cement (OPC)
  - Water demand may be slightly higher due to fineness
  - Early strengths may be higher
  - Set time should be equal
  - Color is slightly lighter

CDOT Specifications – PLC allowed since 2008

- ASTM C1157 GU used initially
- ASTM C595 Type IL introduced in fall 2014

1st CDOT Paving Project w/ PLC
US 287 (Ports to Plains route) in eastern CO

1st CDOT PLC Project @ 11 years old (2019)

1,500 Lane-Miles of Concrete Pavement w/ PLC

US 36
Denver to Boulder

C-470 – SW Denver

Pena Blvd – Access to DEN

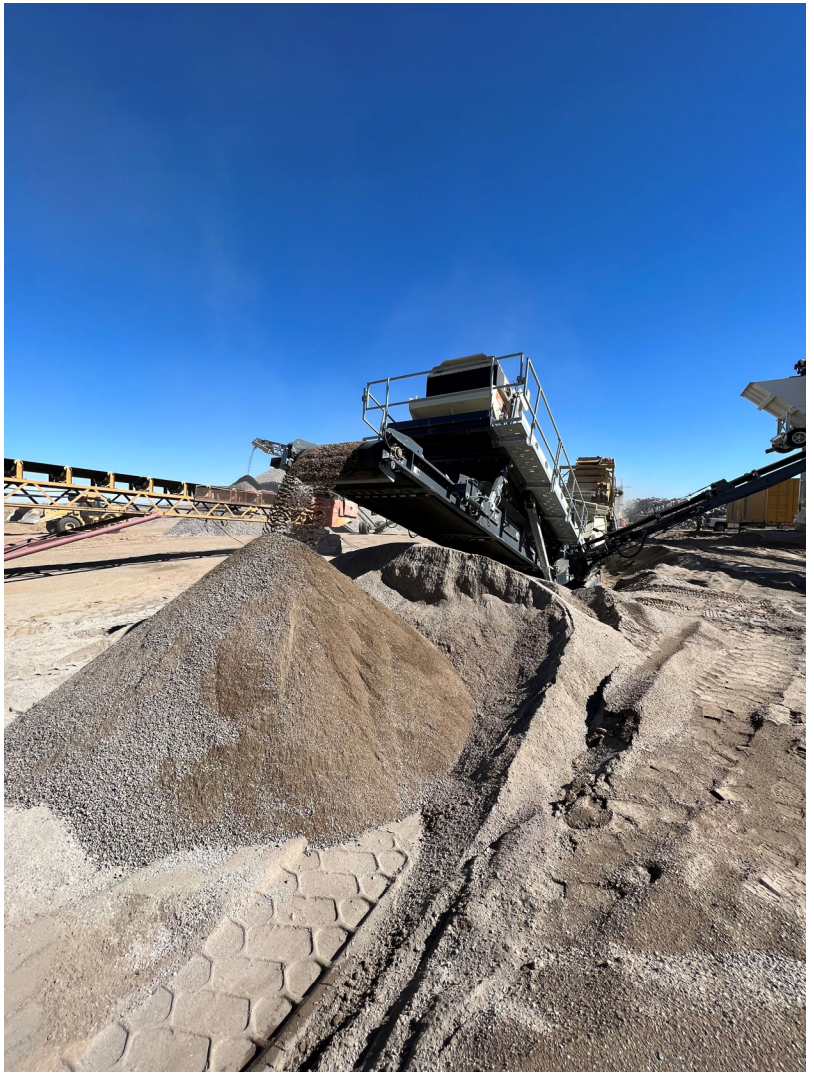
On-Site Aggregate Mining & Concrete Batching

Dramatically reduces truck trips & related emissions

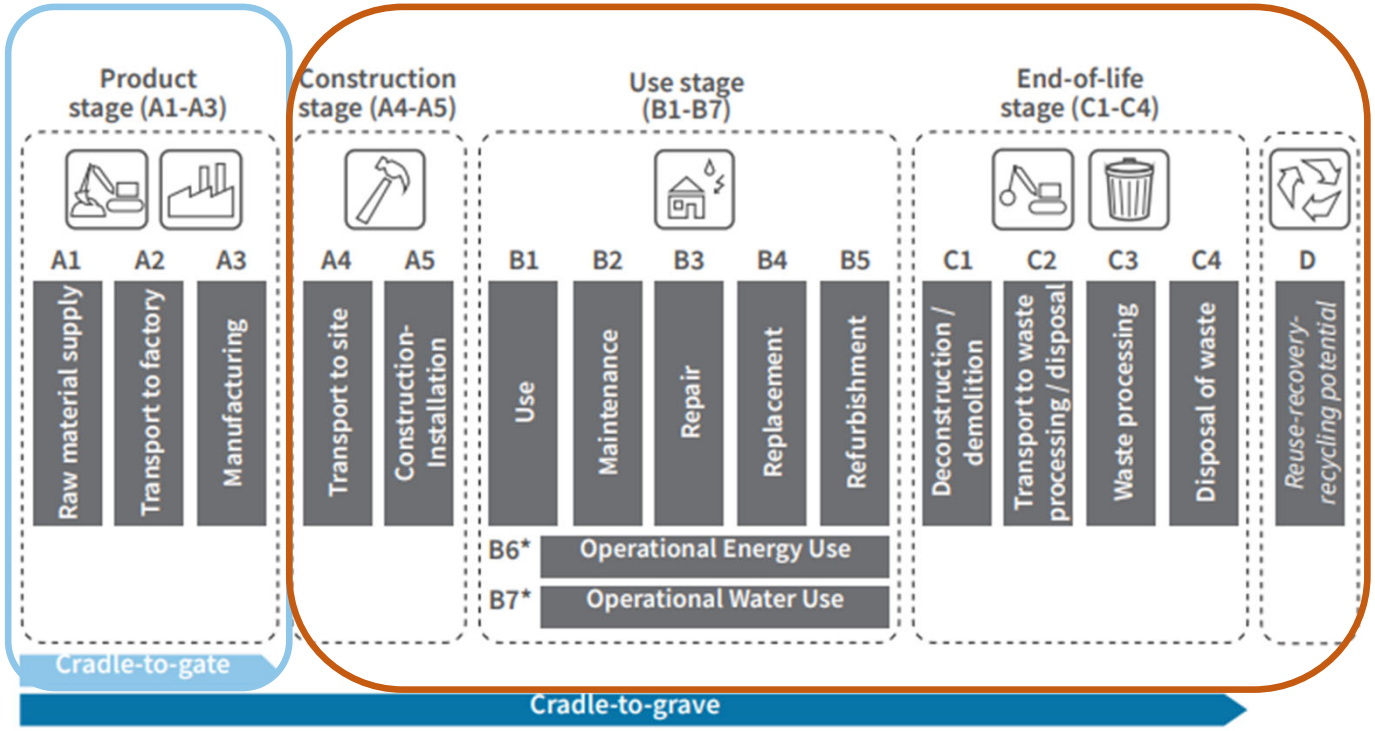
Onsite Concrete Batch Plant & Recycled Concrete Aggregate (RCA)

Recycled Concrete Aggregate (RCA)

Recycled Aggregate Base



EPDs Measure Cradle to Gate Impacts



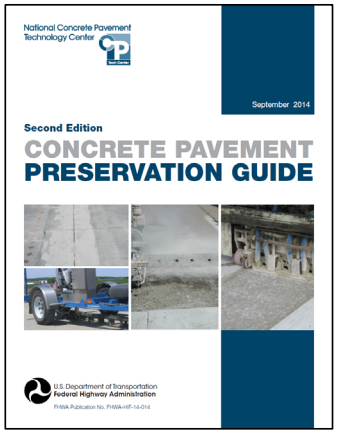
*Operational carbon stages that are typically excluded from life cycle assessments focused on embodied carbon.

Figure 1. Life cycle stages for building products, based on EN 15978:2011 and ISO 21930:2017.

Graphic Source: Carbon Leadership Forum (CLF)

Substantial portion of impacts are not captured through EPDs

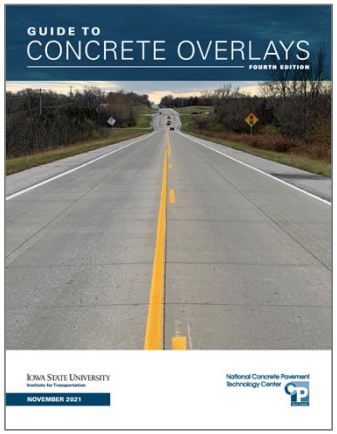
Reducing Gate to Grave Impacts



Pavement preservation/restoration

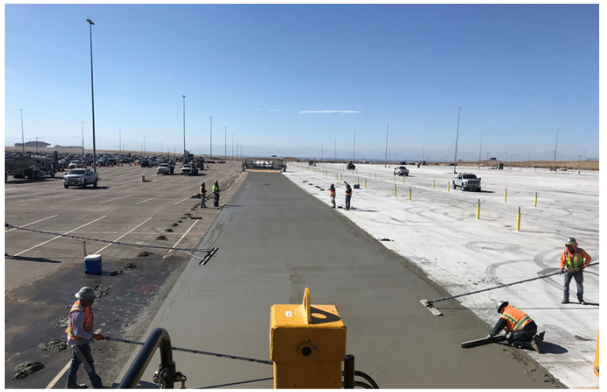
- Extend life of pavement
- Minimize disruption & maximize resource efficiency w/ negligible resource extraction
- Utilize numerous techniques including diamond grinding

Reducing Gate to Grave Impacts



Concrete overlays as preservation

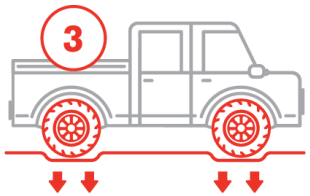
- Resource efficient & eliminates disposal
- Cost effective & quick to construct
- Long life



Pavement Vehicle Interaction (PVI)

ROUGHNESS: whether the road is bumpy or smooth. Roughness, commonly seen and felt as the presence of cracks and potholes, has a significant impact on passenger vehicles.

TEXTURE: the abrasiveness of the road surface, which relates to vehicle traction when the surface is wet.



DEFLECTION: the bending of a pavement under the weight of a vehicle. Deflection is present from the initial construction, and depends on pavement design. Think of the difference between walking or riding on sand versus a paved surface.

The amount of fuel used is impacted by the quality of the roads we drive on.

CSHub studies suggest that excess fuel consumption can be significantly reduced by building **stiffer** roads and maintaining **smoother** pavements.

Source: MIT Concrete Sustainability Hub - CSHUB.MIT.EDU/PAVEMENTS/PVI

Albedo

How is albedo measured?

Albedo is a ratio expressed on a scale from 0 to 1. A surface with an albedo of 0 would be impossibly dark, taking in 100% of solar energy. A surface with an albedo of 1 would be completely reflective.

As global temperatures increase, reducing heat on roadways and in cities can help to lower emissions that contribute to climate change, and to improve quality of life.

Albedo is the measure of solar energy reflected by the Earth's surface. **Lighter colored surfaces reflect more light, and have a higher albedo.** Darker surfaces absorb light and have a lower albedo. Surfaces that absorb heat keep temperatures elevated longer, releasing heat that keeps nearby areas hot even long after the sun has set.

Tackling "Urban Heat Islands" through higher pavement albedo

Increasing pavement albedo in urban areas helps fight urban heat island (UHI) effects that can noticeably decrease our quality of life. **When pavement albedo is increased, lower urban temperatures and fewer extreme heat days and heat waves can result.** UHI events have been directly tied to increased mortality in urban areas.

Source: MIT Concrete Sustainability Hub - CSHUB.MIT.EDU/PAVEMENTS/ALBEDO

Summary

- Focus on durability leads to sustainable pavements
- PLC’s have a long history of use and performance
- Many steps have already been taken
- 25% reduction prior to legislation requirements
- Working with local agencies to implement sustainable and durable approaches to concrete
- Concrete industry is committed to partnering with CDOT for further reductions

Thank You!

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