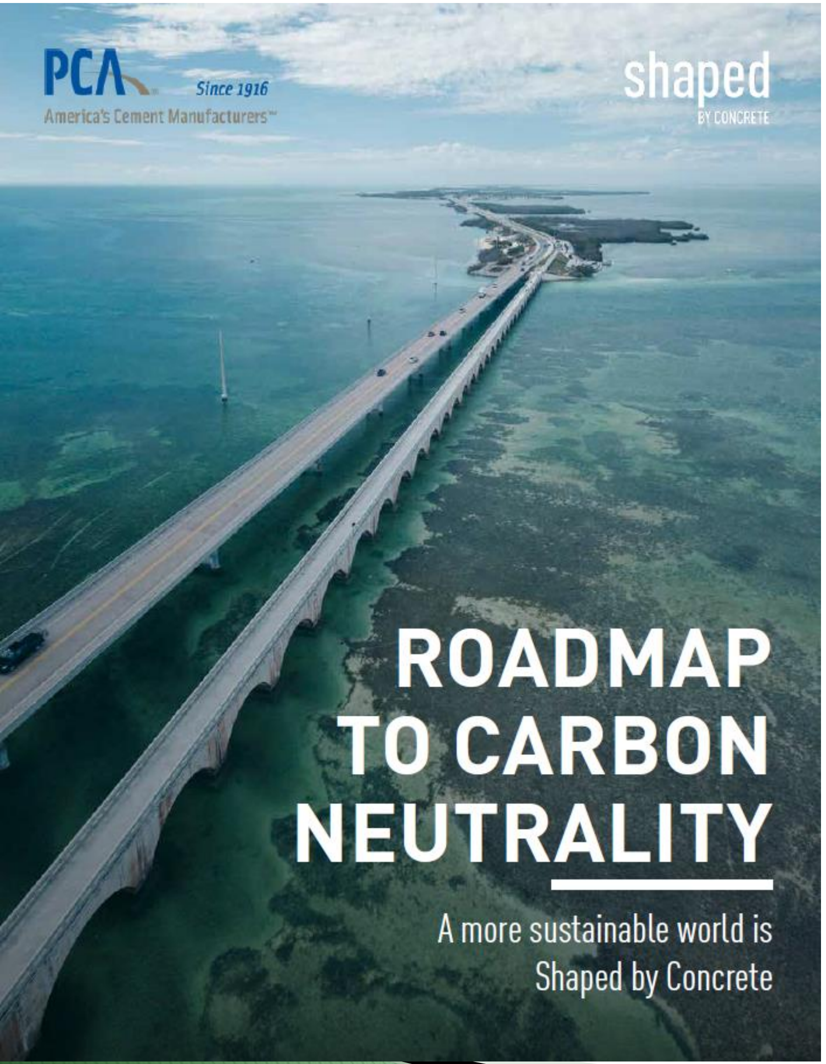
Environmental Product Declarations – Concrete Treatments

Brian Killingsworth, P.E.

National Ready Mixed Concrete Association

NATIONAL PAVEMENT PRESERVATION CONFERENCE
NPPC23
IMPACTS AND BENEFITS FROM PAVEMENT PRESERVATION
ncpp National Center for Pavement Preservation
MICHIGAN STATE UNIVERSITY
AASHTO TSP2 PAVEMENT PRESERVATION
ROCKY MOUNTAIN WEST PAVEMENT PRESERVATION PARTNERSHIP
SOUTHEAST PAVEMENT PRESERVATION PARTNERSHIP
MIDWESTERN PAVEMENT PRESERVATION PARTNERSHIP
NORTHEAST PAVEMENT PRESERVATION PARTNERSHIP

Roadmap to Carbon Neutrality: Cement & Concrete



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

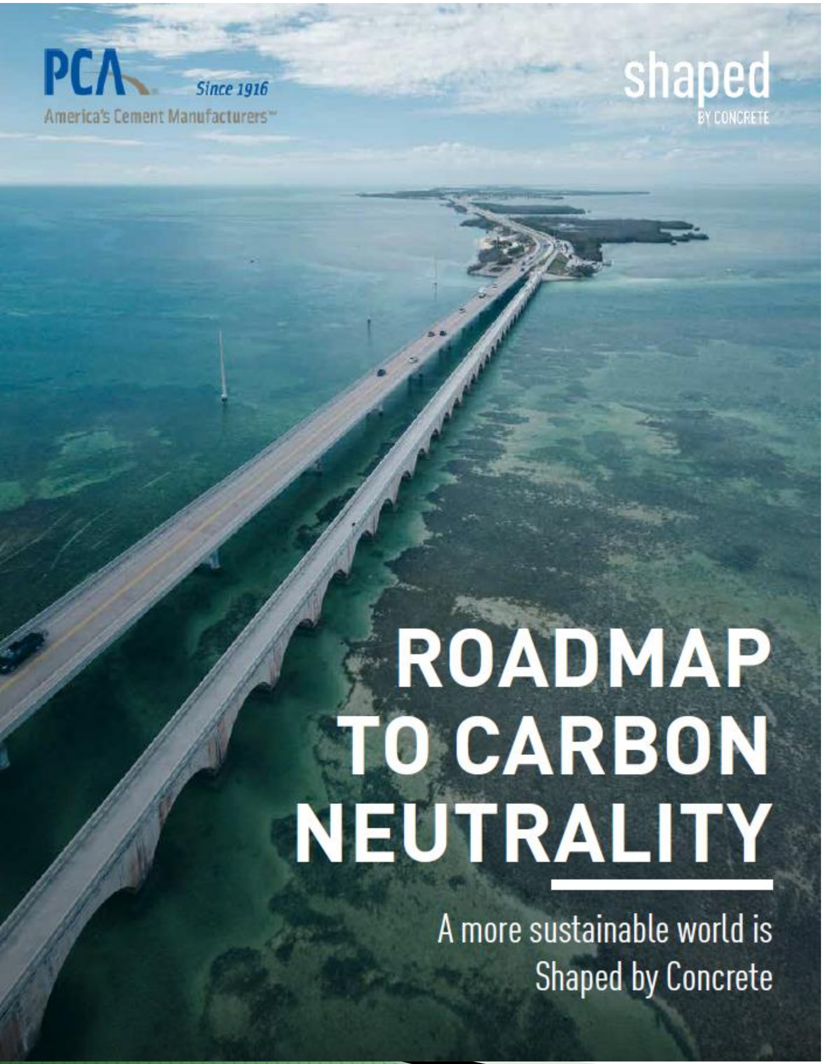
The cement and concrete industries are committed to achieving carbon neutrality across the value chain by 2050.

Achieving carbon neutrality will require combining actions across the supply chain.

The roadmap highlights these strategies and actions.

Source: PCA

Roadmap to Carbon Neutrality: Cement & Concrete



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

NEAR-TERM

- Replace raw materials with recycled materials
- Produce low-carbon cement blends
- Optimize designs for the lowest life cycle emissions

MID-TERM

- Increase the use of alternative fuels
- Use renewable energy

LONG-TERM

- Carbon capture
- Introduce new cement blends

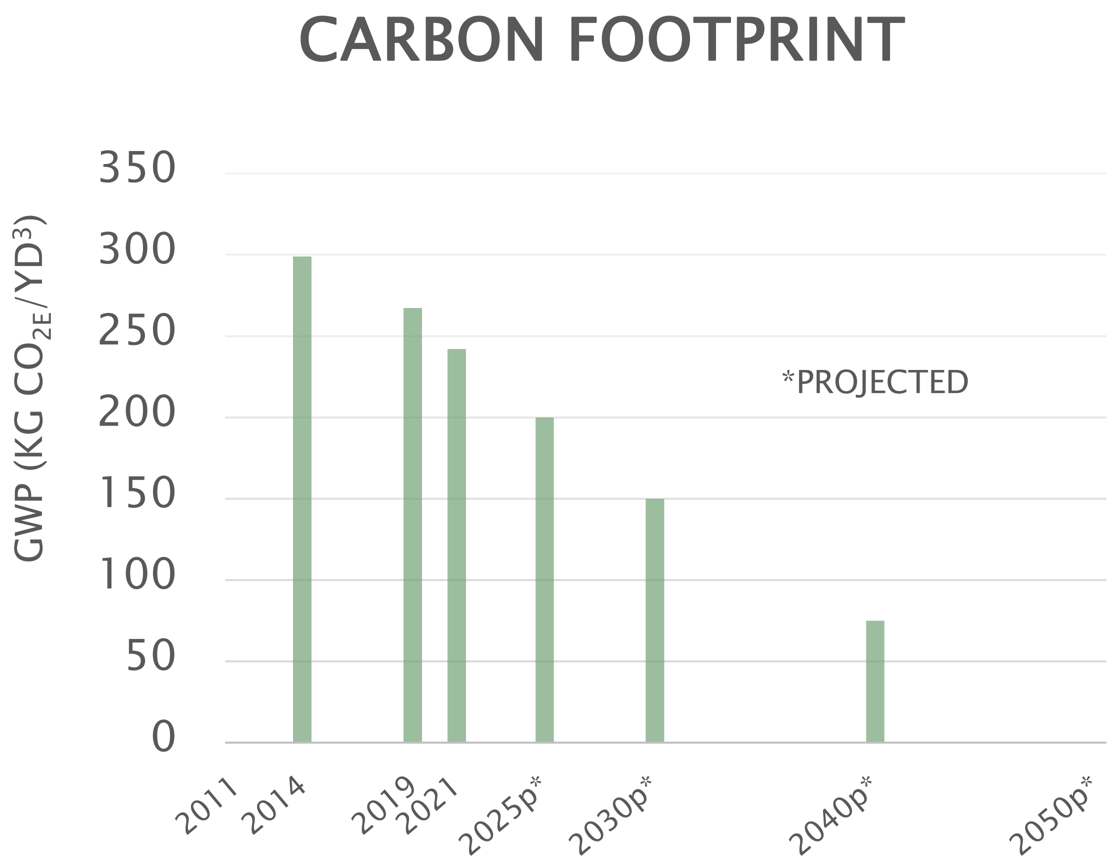
Source: PCA

Ready Mixed Concrete GWP Progress and Plan

Based on Industry Wide EPD:

- 21% Reduction from 2014-2022
- 50% Reduction by 2030*
- 100% Reduction by 2050*

*from 2014 as baseline



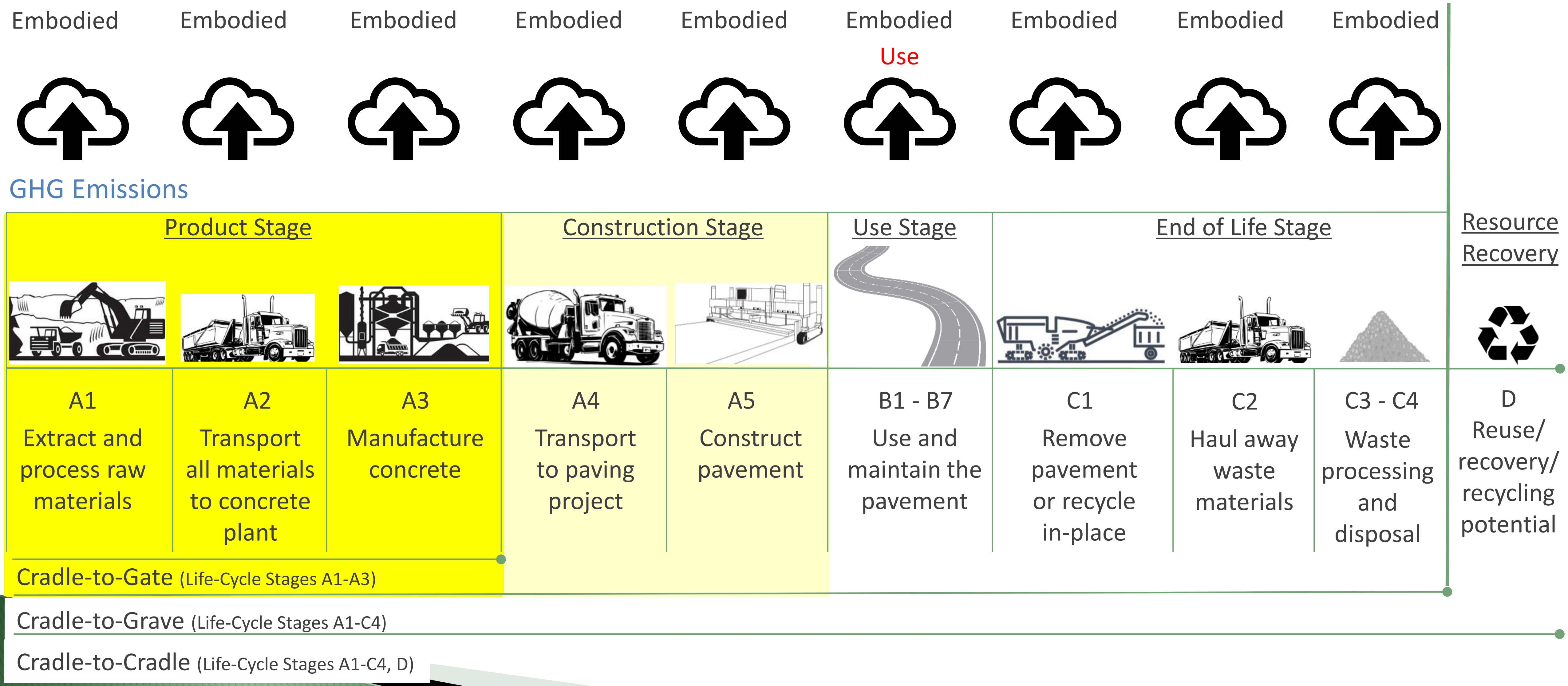
Concrete Product Category Rule (PCR) – Revision History

Version	Date issued
Version 1 (published by Carbon Leadership Forum)	November 2012
Version 1.1 (published by Carbon Leadership Forum)	December 2013
Version 2 (published by NSF International)	February 2019
Version 2.1 (published by NSF International)	August 2021

Version 2.2 (published by NSF International)   December 2022   Consideration of Mobile Mixers

Valid through February 22, 2024

Concrete Pavement (or Bridge) Life-Cycle Stages: Embodied and Operational (Use) GHG Emissions



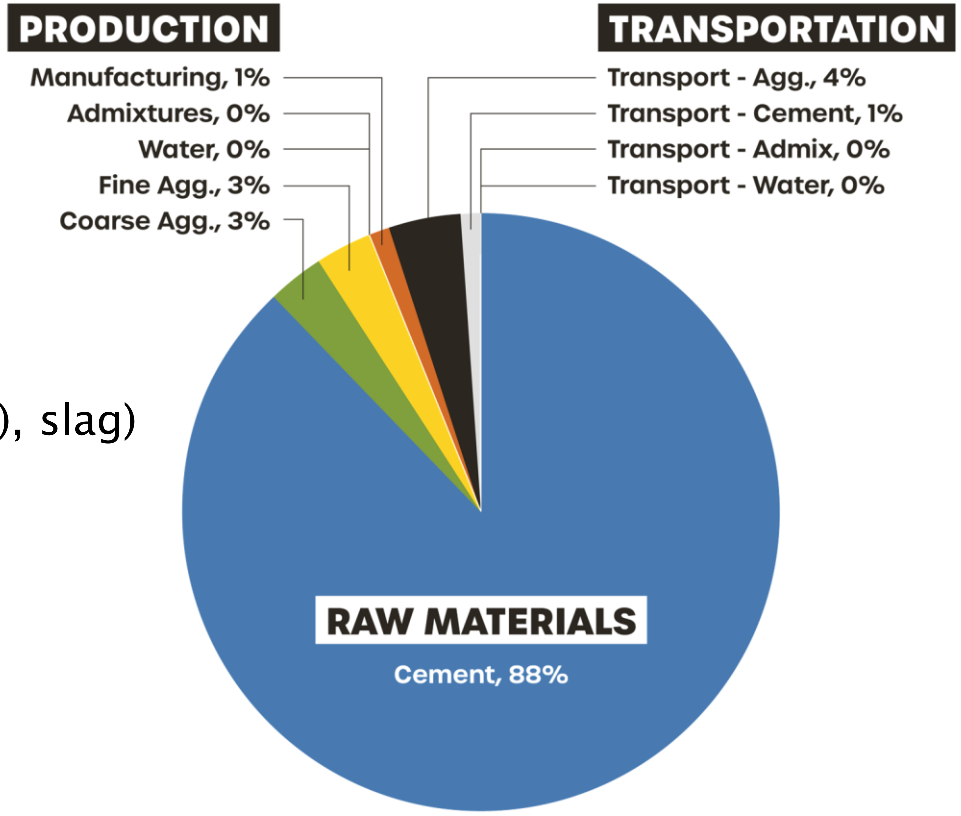
PCR Status: Concrete and Components

Concrete

- Revised PCR to be published in February 2024
- Plan for concrete products PCR to address other life-cycle stages

Component Materials

- Cement (Portland, blended, masonry, mortar, and plastic (stucco), slag)
- SCM (Coal ash, silica fume, natural pozzolans, ground glass)
- Aggregates (Construction and ESCS LW aggregate)
- Admixtures and Fibers (Currently use EN standards)
- Water (Considered in background data)



PCR Status – Concrete Components and Products

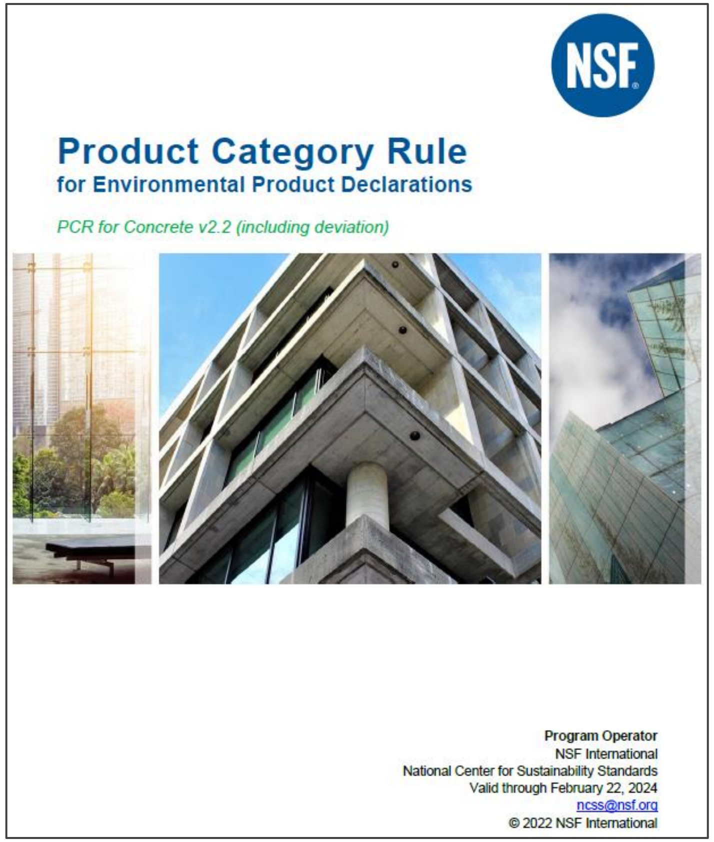
Material	PCR Program Operator	Current Version	Valid Through	Industry Wide	Comments
Concrete	NSF International	2.2	Feb-24	Yes	IW and Regional Benchmarking; Calculator Tool available (Fall 2023).
Portland, Blended, Masonry, Mortar, and Plastic (Stucco) Cements	NSF International	3.2	Mar-25	Yes	IW portland, portland-limestone, blended hydraulic, masonry
Slag Cement	NSF International	2.0	Dec-25	Yes	LCA Calculator Tool available
Construction Aggregates	NSF International	3.0	Dec-23	No	Revised PCR expected late 2023 / early 2024
Expanded Shale, Clay and Slate Lightweight Aggregate	UL Environment	2.0	Jan-26	No	ESCS agg embodied energy/CO_2 reported (2006 data)
Supplementary Cementitious Materials	Developer: SmartEPD	-	-	-	In Review
Cements that Require Carbonation Curing	Developer: SmartEPD	-	-	-	In Development
Admixtures/Fibers	None Currently	-	-	-	Some EPDs published based on ISO 21930 / EN 15804
Precast Concrete	NSF International	3.0	Apr-26	Yes	IW structural, architectural & insulated, glass fiber reinforced

Environmental Product Declarations: Impacts Reported

(There are also economic and social impacts to consider that are not reported in an EPD)

Minimum Impacts to be Reported in EPD (per concrete PCR):

- *global warming potential (GWP 100)*
- ozone depletion potential (ODP)
- eutrophication potential (EP)
- acidification potential (AP)
- photochemical smog creation potential (POCP)
- abiotic depletion potential for non-fossil mineral resources (ADP elements)
- abiotic depletion potential for fossil resources (ADP fossil)
- total waste disposed (kg)
- consumption of freshwater (per ISO 21930:2017, Section 7.2.13)



Product Category Rule

for Environmental Product Declarations

PCR for Concrete v2.2 (including deviation)

Program Operator
NSF International
National Center for Sustainability Standards
Valid through February 22, 2024
ncss@nsf.org
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Additional (Optional) Impacts That May be Reported (per concrete PCR):

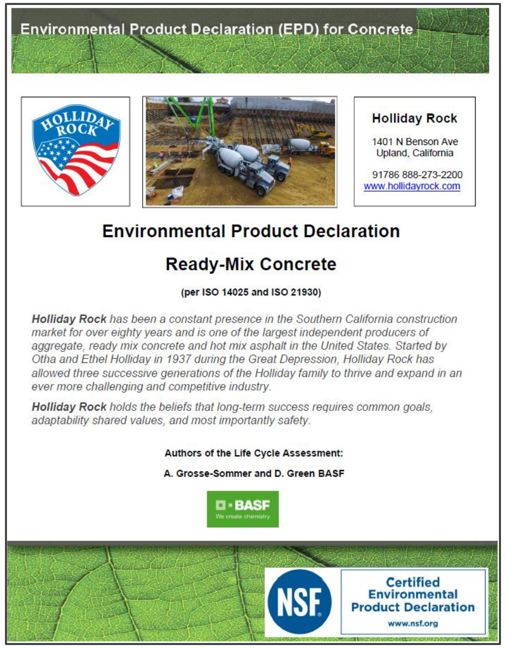
- carbon sequestered in product (kg)

Concrete Industry EPD Process

1. Submitting Company Selects a Program Operator.
2. Submitting Company Gathers Data per Product Category Rule (PCR).
3. Conduct Life-Cycle Assessment (LCA) by In-House Staff or LCA Consultant.
4. Develop Draft EPD by In-House Staff or LCA Consultant.
5. Submit the LCA Report and Draft EPD to Program Operator for Initial Verification.
6. Program Operator Engages Independent Verifier Who Reviews the LCA Report and Draft EPD.
7. Program Operator Certifies EPD for Submitting Company.

**Pre-verified software may be used to generate on-demand EPDs thus reducing the number of steps.

Concrete Embodied Emissions: Environmental Product Declarations



Environmental Product Declaration (EPD) for Concrete

Holliday Rock
1401 N Benson Ave
Upland, California
91786 888-273-2200
www.hollidayrock.com

Environmental Product Declaration

Ready-Mix Concrete

(per ISO 14025 and ISO 21930)

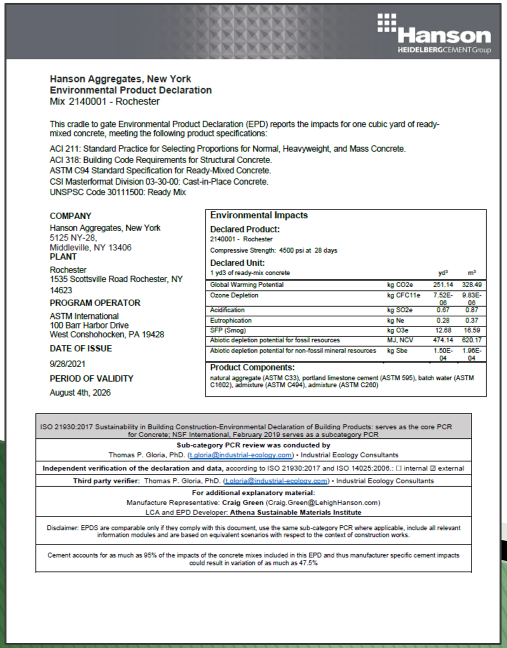
Holliday Rock has been a constant presence in the Southern California construction market for over eighty years and is one of the largest independent producers of aggregate, ready mix concrete and hot mix asphalt in the United States. Started by Otha and Ethel Holliday in 1937 during the Great Depression, Holliday Rock has allowed three successive generations of the Holliday family to thrive and expand in an ever more challenging and competitive industry.

Holliday Rock holds the beliefs that long-term success requires common goals, adaptability shared values, and most importantly safety.

Authors of the Life Cycle Assessment:

A. Grosse-Sommer and D. Green BASF

Certified Environmental Product Declaration
www.nsf.org



Hanson Aggregates, New York
Environmental Product Declaration
Mix 2140001 - Rochester

This cradle to gate Environmental Product Declaration (EPD) reports the impacts for one cubic yard of ready-mixed concrete, meeting the following product specifications:

ACI 211: Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete.
ACI 318: Building Code Requirements for Structural Concrete.
ASTM C94 Standard Specification for Ready-Mixed Concrete.
CSI Masterformat Division 03-30-00: Cast-in-Place Concrete.
UNSPSC Code 30111500: Ready Mix

COMPANY
Hanson Aggregates, New York
5125 NY-28,
Middleville, NY 13406

PLANT
Rochester
1535 Scottsville Road Rochester, NY 14623

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

DATE OF ISSUE
9/28/2021

PERIOD OF VALIDITY
August 4th, 2026

Environmental Impacts

Declared Product:
2140001 - Rochester
Compressive Strength: 4500 psi at 28 days

Declared Unit:
1 yd3 of ready-mix concrete

		yd³	m³
Global Warming Potential	kg CO2e	251.14	328.49
Ozone Depletion	kg CFC11e	7.52E-06	9.83E-06
Acidification	kg SO2e	0.67	0.87
Eutrophication	kg Ne	0.28	0.37
SFP (Smog)	kg O3e	12.68	16.59
Abiotic depletion potential for fossil resources	MJ, NCV	474.14	620.17
Abiotic depletion potential for non-fossil mineral resources	kg Sbe	1.50E-04	1.96E-04

Product Components:
natural aggregate (ASTM C33), portland limestone cement (ASTM 595), batch water (ASTM C1602), admixture (ASTM C494), admixture (ASTM C260)

ISO 21930:2017 Sustainability in Building Construction-Environmental Declaration of Building Products: serves as the core PCR for Concrete; NSF International, February 2019 serves as a subcategory PCR

Sub-category PCR review was conducted by
Thomas P. Gloria, PhD. (t.gloria@industrial-ecology.com) • Industrial Ecology Consultants

Independent verification of the declaration and data, according to ISO 21930:2017 and ISO 14025:2006.: ☐ internal ☑ external

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

For additional explanatory material:
Manufacture Representative: **Craig Green** (Craig.Green@LehighHanson.com)
LCA and EPD Developer: **Athena Sustainable Materials Institute**

Disclaimer: EPDS are comparable only if they comply with this document, use the same sub-category PCR where applicable, include all relevant information modules and are based on equivalent scenarios with respect to the context of construction works.

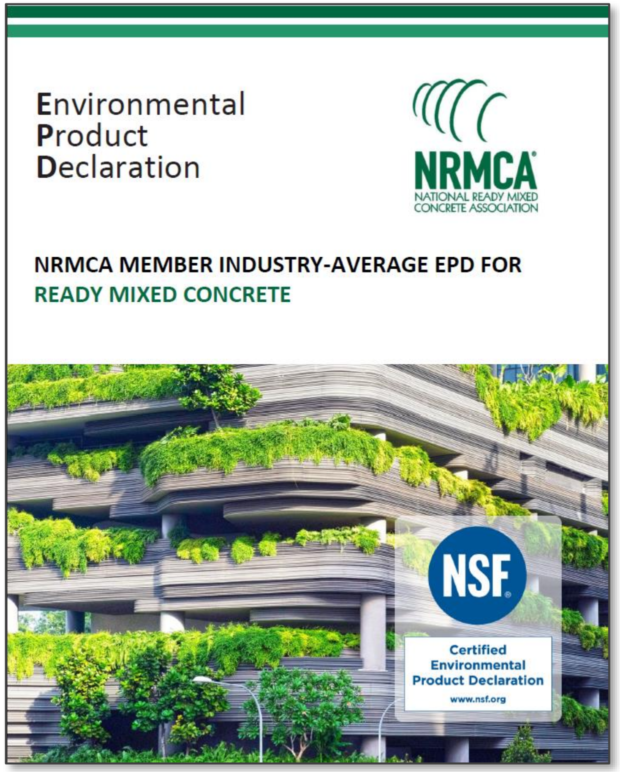
Cement accounts for as much as 95% of the impacts of the concrete mixes included in this EPD and thus manufacturer specific cement impacts could result in variation of as much as 47.5%

- **~84,000* valid product specific EPDs published by concrete producers in <u>U.S.</u> and <u>Canada</u> (as of September 2023)**
  - Concrete GWP Values for All Mixtures (<u>U.S. and Canada from EC3 Tool</u>):
    - Conservative (Baseline set @ 80th percentile): 348 $kgCO_{2e}/yd^3$
    - Average (Typical set @ Arithmetic Mean & COV): 289 $kgCO_{2e}/yd^3 \pm 26.8\%$
    - Achievable (Low-Carbon set @ 20th percentile): 226 $kgCO_{2e}/yd^3$

*Based on <u>Embodied Carbon in Construction Calculator (EC3) Tool</u> initiated by the Carbon Leadership Forum and published by Building Transparency which is very <u>comprehensive</u> but not <u>exhaustive</u>.

*<u>***GWP benchmarks should be established locally and by mix type/use***</u>*

Concrete Industry Wide Environmental Product Declaration



https://www.nrmca.org/wp-content/uploads/2022/03/NRMCA_EPDV3-2_20220301.pdf

- Ready Mixed Concrete Industry Wide EPD (v3.2) Jan 2022 – Nov 2024
- Currently Collecting Data for Revised IW EPD to be Published Dec 2024
- Based on NRMCA Member Data (100+ Companies & ~2,000 Plants)
- Concrete GWP Values from IW EPD (calculated at ↑strength & ↓SCM ranges):

Industry Average EPD (Published January 3rd, 2022)										
28-day f'c, psi	Minimum	Maximum	0% FA/SL	20% FA	30% FA	40% FA	30% SL	40% SL	50% SL	50% FA/SL
Conventional Concrete GWP (per yd^3)										
0 - 2,500	136.6	213.7	213.7	184.7	169.1	152.6	168.0	152.8	137.5	136.6
2,501 - 3,000	150.7	238.1	238.1	205.2	187.4	168.8	186.1	168.9	151.7	150.7
3, 001 - 4,000	182.5	293.3	293.3	251.7	229.1	205.5	227.5	205.6	183.7	182.5
4,001 - 5,000	220.3	358.5	358.5	306.6	278.6	249.0	276.5	249.2	221.8	220.3
5,001 - 6,000	231.5	377.4	377.4	322.6	293.0	261.7	290.8	262.0	233.1	231.5
6,001 - 8,000	266.9	438.9	438.9	374.4	339.5	302.6	336.9	302.9	268.9	266.9
Lightweight Aggregate Concrete GWP (per yd^3)										
0 - 3,000	303.0	426.4	426.4	367.2	335.2	360.0	305.7	340.8	303.0	321.6
3,001 -4,000	343.6	491.2	491.2	424.0	385.0	414.7	348.2	390.3	343.6	362.5
4,001 - 5,000	373.6	547.6	547.6	468.5	422.4	455.3	380.1	427.5	373.6	394.4

Supplementary Cementitious Material (SCM) Ranges:
0-19% Fly Ash and/or Slag, 20-29% Fly Ash, 30-39% Fly Ash, 40-49% Fly Ash, 30-49% Slag, 40-39% Slag, ≥ 50% Slag, ≥ 20% Fly Ash and ≥ 30% Slag

- **NRMCA members decreased their carbon footprint by 21% in 7 years**

Concrete Regional LCA Benchmark Report

Region	28-Day Compressive Strength, psi								
	2,500	3,000	4,000	5,000	6,000	8,000	3,000LW	4,000LW	5,000LW
	Global Warming Potential (per yd^3)								
National	183.5	200.6	235.6	279.0	294.6	341.3	376.4	412.9	449.8
Eastern	183.3	201.5	240.2	289.0	305.3	360.5	395.4	437.9	480.1
Great Lakes Midwest	177.6	194.8	231.4	277.6	293.1	345.3	381.6	421.6	461.3
North Central	184.2	201.9	238.8	284.7	301.5	351.8	372.1	410.7	451.7
Pacific Northwest	180.0	199.8	242.0	295.2	311.9	372.7	396.2	439.7	483.4
Pacific Southwest	196.5	213.5	247.3	288.9	306.4	349.0	382.2	417.5	453.9
Rocky Mountains	177.5	194.6	229.8	273.4	289.6	336.7	369.8	406.5	443.5
South Central	172.4	187.7	218.6	257.2	272.2	312.8	357.7	390.2	424.5
South Eastern	188.9	204.6	236.5	275.5	292.1	332.2	365.6	398.7	429.4

Table B1-NRMCA U.S. National Benchmark Mix Designs (per cubic yard)

Compressive Strength	psi	2500	3000	4000	5000	6000	8000	3000 LW	4000 LW	5000 LW
Portland Cement	lbs	354	394	475	576	610	719	394	475	556
Fly Ash	lbs	62	69	83	101	107	126	69	83	97
Slag Cement	lbs	17	19	23	28	30	35	19	23	27
Mixing Water	lbs	305	305	305	315	341	341	308	308	308
Crushed Coarse Aggregate	lbs	1,126	1,115	1,083	1,029	1,061	1,018	0	0	0
Natural Coarse Aggregate	lbs	553	547	531	505	521	499	0	0	0
Crushed Fine Aggregate	lbs	169	167	162	154	159	152	161	149	136
Natural Fine Aggregate	lbs	1,282	1,270	1,233	1,171	1,208	1,159	1,225	1,130	1,035
Man.Lightweight Aggregate	lbs	0	0	0	0	0	0	980	990	1,000
Air %	%	6%	6%	6%	6%	6%	0	6%	6%	2%
Air Entraining Admixture	oz	1	1	1	1	1	1	1	1	0
Plasticizer & Superplasticizer	oz	3	3	3	7	3	3	3	7	7
Set Accelerator	oz	25	20	15	10	25	20	15	10	10
Total Weight	lbs	3,867	3,886	3,895	3,878	4,037	4,049	2,178	2,168	2,159

- Published by NRMCA July 2022 (v3.2)
- Region Specific Mixtures For:
  - 6 Conventional Concrete Mixtures &
  - 3 Lightweight Concrete Mixtures
  - Complements IW EPDs with average data for 8 regions

Optimization – Compare to Benchmark

4,000 psi @ 28 days
w/Portland Limestone Cement
Opelika, AL

CEMEX
ENVIRONMENTAL PRODUCT DECLARATION
Mix 1621528 • Opelika Plant

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
CEMEX
10100 Katy Freeway, Suite 300
Houston, TX 77043

PLANT
Opelika Plant
2101 POPLAR STREET
Opelika, AL 36801

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

DATE OF ISSUE
08/13/2022 (valid for 5 years until 08/13/2027)

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

For additional explanatory material
Manufacture Representative: Chris Bailey (robertc.bailey@rmusa.cemex.com)
Software Tool: CarbonCLARITY Suite, EPD Generator • Verification
LCA & EPD Developer: Climate Earth (support@climateearth.com)

CEMEX
10100 Katy Freeway, Suite 300
Houston, TX 77043
713-650-6200

OPELIKA
2101 POPLAR STREET
Opelika, AL 36801

ENVIRONMENTAL IMPACTS

Declared Product:
Mix 1621528 • Opelika Plant
Description: 4000 PAVING
Compressive strength: 4000 PSI at 28 days

Declared Unit: 1 m^3 of concrete

Global Warming Potential (kg CO_2-eq)	300
Ozone Depletion Potential (kg CFC-11-eq)	7.69E-6
Acidification Potential (kg SO_2-eq)	0.97
Eutrophication Potential (kg N-eq)	0.35
Photochemical Ozone Creation Potential (kg O_3-eq)	21.1
Abiotic Depletion, non-fossil (kg Sb-eq)	7.26E-5
Abiotic Depletion, fossil (MJ)	742
Total Waste Disposed (kg)	84.1
Consumption of Freshwater (m^3)	3.41

Product Components: crushed aggregate (ASTM C33), natural aggregate (ASTM C33), type 1L cement (ASTM C595), fly ash (ASTM C618), batch water (ASTM C1602), admixture (ASTM C494), admixture (ASTM C260)

DECLARATION OF ENVIRONMENTAL INDICATORS DERIVED FROM LCA

Impact Assessment	Unit	A1	A2	A3	Total
Global warming potential	kg CO_2-eq	266	25.2	9.19	300
Depletion potential of the stratospheric ozone layer (ODP)	kg CFC-11-eq	7.40E-6	1.07E-9	2.94E-7	7.69E-6
Eutrophication potential	kg N-eq	0.30	0.02	0.03	0.35
Acidification potential of soil and water sources (AP)	kg SO_2-eq	0.55	0.32	0.10	0.97
Formation potential of tropospheric ozone (POCP)	kg O_3-eq	10.1	8.07	2.92	21.1

Athena Sustainable Materials **Institute** www.athenasmi.org

A Cradle-to-Gate Life Cycle Assessment of Ready-Mixed Concrete Manufactured by NRMCA Members – Version 3.2

This project report and its results are used to support the development of an industry wide or sector average Environmental Product Declaration for the production of 72 concrete mix designs

Comissioner: National Ready Mixed Concrete Association (NRMCA)

EPD Program Operator: NSF International

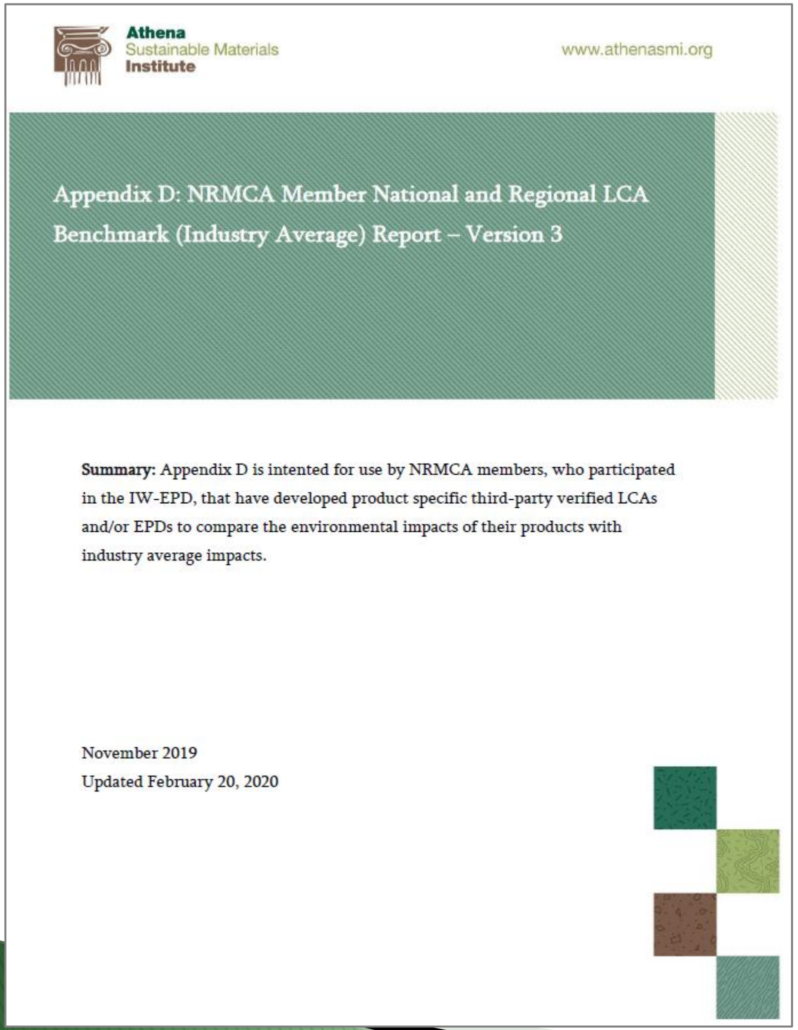
Prepared by: The Athena Sustainable Materials Institute

July 2022

Table F9-South Eastern LCA Results (per cubic meter)

Strength	psi @28 days	2,500	3,000	4,000	5,000	6,000	8,000	3000LW	4000LW	5000LW
Core Mandatory Impact Indicator										
GWP	kg CO2e	247.01	267.61	309.37	360.37	382.02	434.55	478.12	521.48	561.68
ODP	kg CFC11e	5.52E-06	7.68E-06	8.61E-06	9.72E-06	1.03E-05	1.14E-05	1.77E-05	1.87E-05	1.96E-05
AP	kg SO2e	0.72	0.99	1.09	1.21	1.27	1.40	2.41	2.52	2.62
EP	kg Ne	0.24	0.33	0.38	0.43	0.46	0.51	0.83	0.88	0.93
SFP	kg O3e	16.39	22.42	24.47	26.88	28.19	30.76	33.22	35.35	37.30
ADPf	MJ, NCV	435.97	583.68	614.20	653.02	682.35	720.05	2,478.97	2,528.50	2,562.73
ADPe	kg Sbe	1.31E-04	1.74E-04	1.79E-04	1.84E-04	1.92E-04	1.98E-04	2.20E-04	2.27E-04	2.33E-04

Benchmark Data: Regional Benchmark 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

NRMCA Regional Benchmark Report

- Next report (v4) targeting sub-regional average data (2024)
- More granular benchmark data may be challenging to obtain
  - Government grants and incentives can help
  - Data from other sources (public agencies) can help
- Considering publishing interim benchmarks by end of 2023

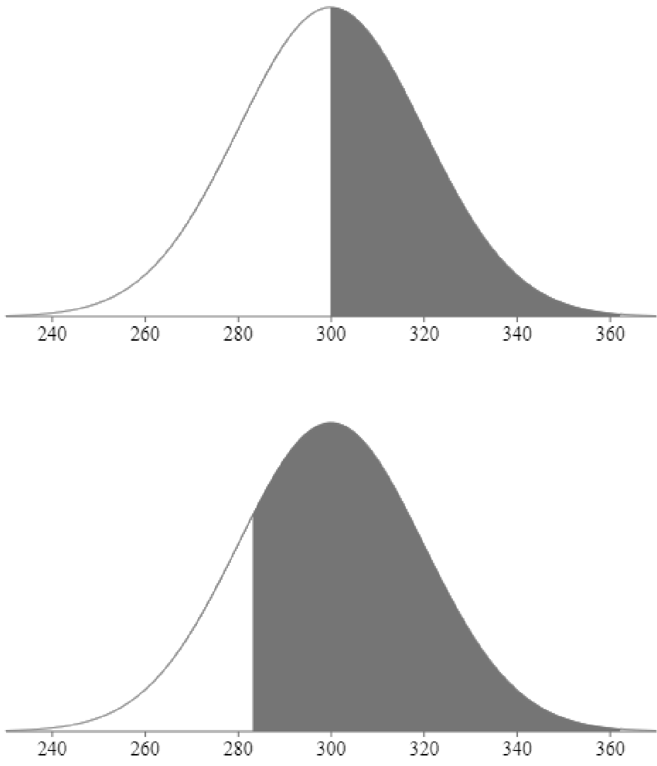
PCRs and EPDs for Concrete Treatments

Treatment Types	Common Treatment Material(s)	PCR Available?	EPDs Available?
Concrete overlay Full-depth repair	Concrete	Concrete (NSF)	Yes
Partial-depth repair	Concrete, epoxy-resins	No for epoxy resins	Yes for concrete
Full-depth reclamation	Cement	Portland, Blended Hydraulic, Masonry, Mortar, and Plastic Stucco Cements (ASTM)	Yes
Crack sealing Joint resealing	Rubberized asphalt binder, asphaltic resins, synthetic polymer rubbers, silicones (ASTM D6690 Type I-IV)	Building and Construction Sealant (UL)	Yes but limited
Diamond grinding Diamond grooving	Diamond tipped blades and grinders	N/A	N/A
Dowel bar retrofit Cross-stitching Slot-stitching	Rebar and epoxy coated rebar	Designated Steel Construction Product (UL)	Yes
Slab stabilization Slab jacking	Polyurethane, cement grout, asphalt cement	No for polyurethane; Asphalt binder in development	Yes for cement
Retrofitted edgedrains	Pipe, aggregate	Construction Aggregates (ASTM expired); No for edgedrain pipe	Yes but limited

Options for Reporting Environmental Impacts with EPDs

- All materials provided meet or exceed an established criteria:
  - Criteria: Fall below an average value (by concrete class):
    - Example: Class S concrete < 300 kg CO_{2e}/yd^3
  - Criteria: Fall within a statistical percentile (by concrete class):
    - Example: Class S concrete must be within the lowest 20% of GWP for a population
- Carbon Budget Approach (encourages materials innovation):
  - Set budget for various infrastructure elements (i.e. bridges, pavement/flatwork, drainage structures, etc.)
  - Criteria: Fall below budgeted values

Class S Concrete



Carbon Budgeting:
Bridge Embodied Carbon Impact From Concrete

Establish budget based on bid quantities and expected GWP values (typically based on industry regional benchmark)

Rail: (yd^3) x (GWP) = kg CO_{2e}

Deck: (yd^3) x (GWP) = kg CO_{2e}

Abutments: (yd^3) x (GWP) = kg CO_{2e}

Girders: (yd^3) x (GWP) = kg CO_{2e}

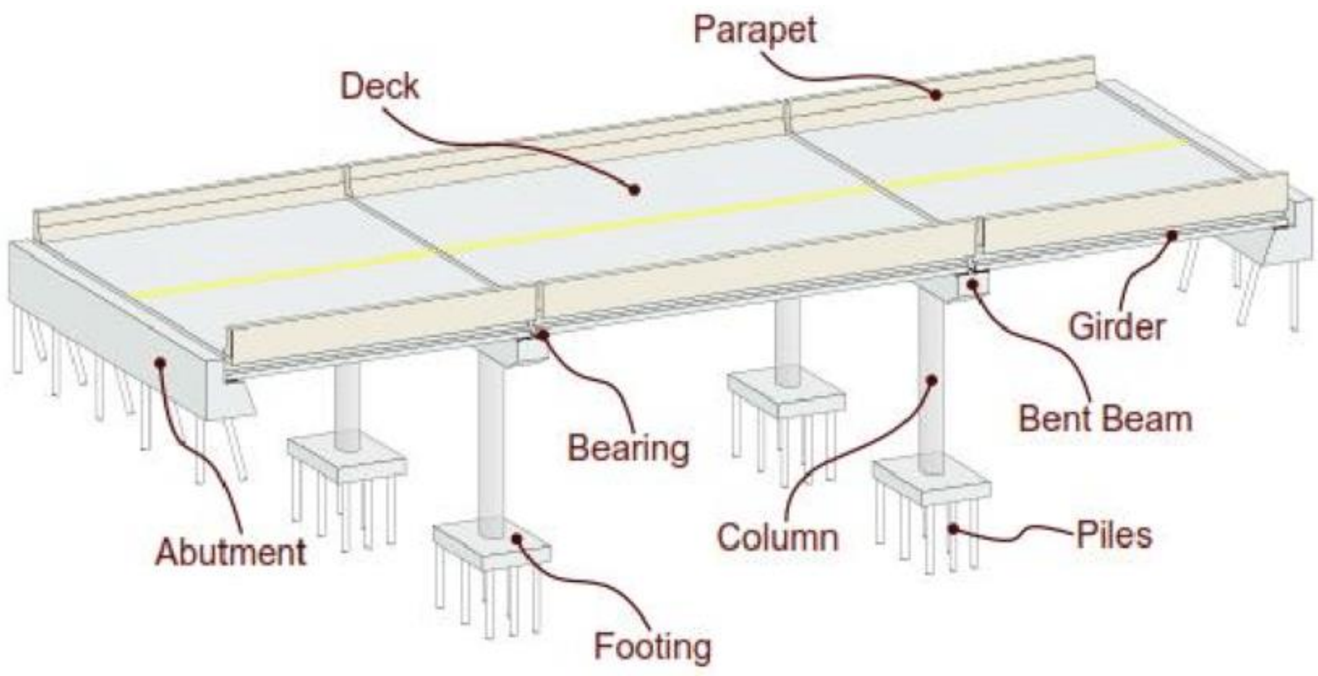
Bents: (yd^3) x (GWP) = kg CO_{2e}

Columns: (yd^3) x (GWP) = kg CO_{2e}

Footings: (yd^3) x (GWP) = kg CO_{2e}

Piles: (yd^3) x (GWP) = kg CO_{2e}

Total Concrete GWP Impact = kg CO_{2e}



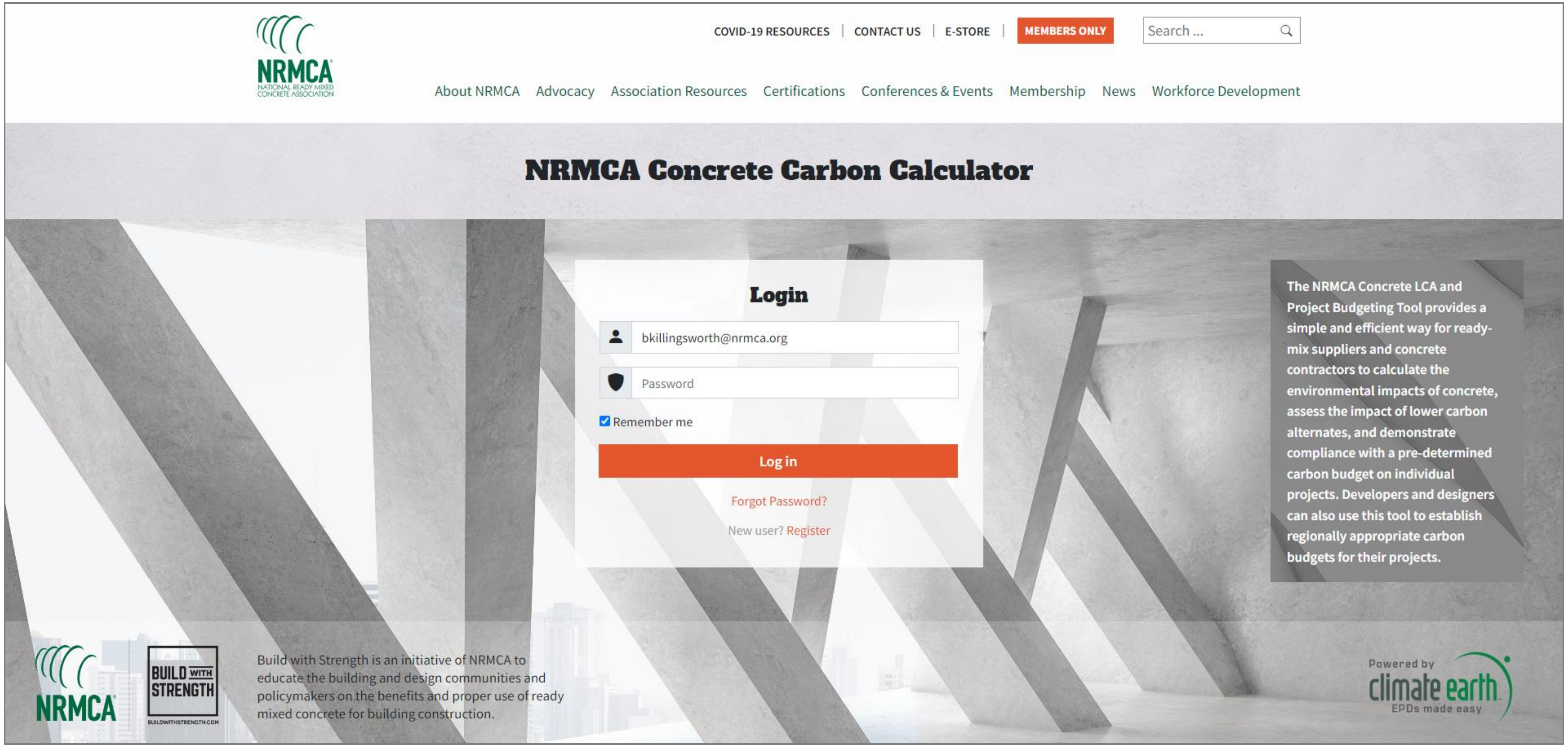
Global Warming Potential (GWP) = kg CO_{2e} / yd^3

Carbon Budgeting:
Bridge Embodied Carbon Impact From Concrete

Actual	Expected
Rail: (yd^3) x (GWP) = kg CO_{2e}	Rail: (yd^3) x (GWP) = kg CO_{2e}
Deck: (yd^3) x (GWP) = kg CO_{2e}	Deck: (yd^3) x (GWP) = kg CO_{2e}
Abutments: (yd^3) x (GWP) = kg CO_{2e}	Abutments: (yd^3) x (GWP) = kg CO_{2e}
Girders: (yd^3) x (GWP) = kg CO_{2e}	Girders: (yd^3) x (GWP) = kg CO_{2e}
Bents: (yd^3) x (GWP) = kg CO_{2e}	Bents: (yd^3) x (GWP) = kg CO_{2e}
Columns: (yd^3) x (GWP) = kg CO_{2e}	Columns: (yd^3) x (GWP) = kg CO_{2e}
Footings: (yd^3) x (GWP) = kg CO_{2e}	Footings: (yd^3) x (GWP) = kg CO_{2e}
Piles: (yd^3) x (GWP) = kg CO_{2e}	Piles: (yd^3) x (GWP) = kg CO_{2e}
Total Concrete GWP Impact = kg CO_{2e}	Total Concrete GWP Impact = kg CO_{2e}

$$\text{Total GWP}_{Actual} \leq \text{Total GWP}_{Expected}$$

NRMCA Concrete Carbon Calculator



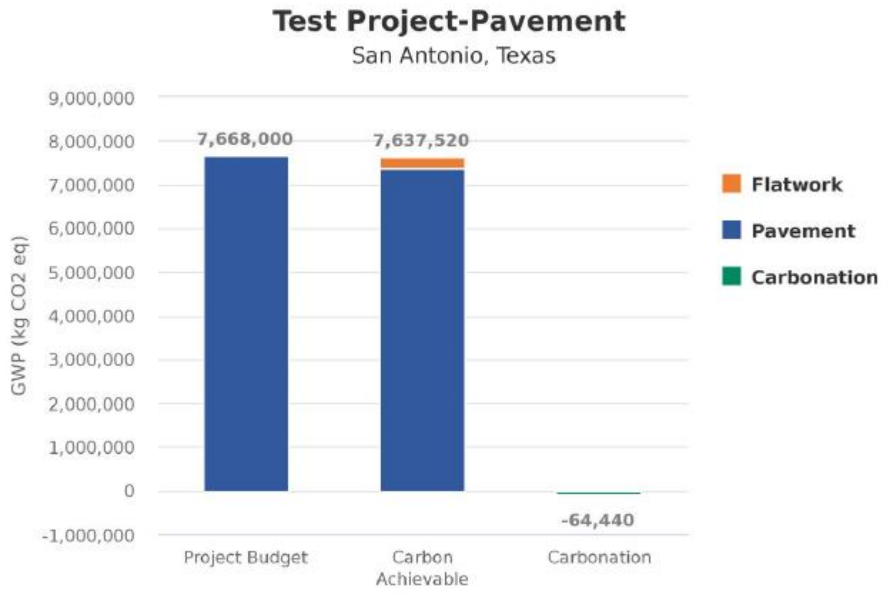
NRMCA Concrete Carbon Calculator

Concrete Budget Report

Contractor: **Best Paving Contractor**

Ready Mix Producer: **BK Ready Mix**

Prepared by: **bkillingsworth@nrmca.org**



Application	Concrete Quantity (yd³)	f'c (PSI)	Proposed MIX GWP (kgCO2e/yd³)	Project GWP Budget (kgCO2e/ project)	Total Project Proposed GWP (kgCO2e/ project)	Difference from Project Budget	Carbonation (kgCO2e/project)
Pavement	30,000	4,000	246.1		7,383,000		-60,000
Flatwork	1,200	3,000	212.1		254,520		-4,440
				7,668,000	7,637,520	**-0.40 %**	-64,440

Reducing Concrete's Embodied Carbon Emissions (In-Use to Near-Term)

- Communicate Carbon Reduction Goals
- Ensure Good Quality Control and Assurance
- Optimize Concrete Designs & Mixtures
- Specify Innovative Cements
- Specify Supplementary Cementitious Materials
- Specify Admixtures
- Don't Limit Ingredients (e.g., PEM)
- Set Targets for Carbon Footprint
- Sequester Carbon Dioxide in Concrete
- Encourage Innovation

Source: NRMCA Top Ten Ways to Reduce Concrete's Carbon Footprint

Specifications – Prescriptive to Performance

- Design multiple concrete mixtures that meet performance specifications
- Allow innovation with materials and construction specification language while balancing risks
- Transitioning to performance-based specifications requires collaboration to share planning and risk among all participants

Reducing Concrete's Embodied Carbon Emissions: (In-Use to Near-Term)

- **Optimized Designs & Rehabilitations**
  - Use innovative design, material, and construction methods.
- **Use of Type IL Cement**
  - Portland-limestone cement containing more than 5% but less than or equal to 15% by mass of limestone.
- **Alternative & Blended Cements / Clinkers**
  - The use of low CO_2 clinker and blended cements.
- **Supplementary Cementitious Materials (SCMs)**
  - Fly Ash, Slag, other pozzolans to optimize the amount of cementitious content in the concrete.
- **Aggregate Optimization**
  - Use well graded mixes to optimize paste and improve workability & durability. On-site concrete recycling.
- **Enhanced Carbonation**
  - Technologies to use CO_2 emissions (e.g., injected CO_2).

Optimizing concrete mixes using these tools allows the Industry to create low carbon ready-mix concrete

Reducing Concrete's Embodied Carbon Emissions: (Mid- to Long-Term)

- **Increase Use of Alternative Fuels at Cement Plants**
  - Utilize transformative fuels and technologies: hydrogen, plasma heating, oxyfuel/oxy-calcination, electric calcination, agriculture and sorted disposed waste…
- **Zero or Low Emissions During Cement and Concrete Manufacturing and Transportation**
  - Move to renewable energy sources for manufacturing and alternative fuels (e.g., hydrogen) or electric power for transportation.
- **Development of New Cements**
  - Use low CO_2 clinker and blended cements, new binders, etc.
- **Carbon Capture Utilization & Storage**
  - Further develop technologies to capture, store, and use CO_2 emissions (e.g., underground storage, enhanced carbonation cement and aggregates, etc.).

Optimizing concrete mixes using these tools allows the Industry to create low carbon ready-mix concrete

GHG Reduction Strategies for Pavements

Strategies have *technical* targets and *timing* of targets and may vary by *region*

System Attribute	Ambitious Improvement Scenario
Material Production	Zero-impact mixtures
Smoothness	Improve at time of construction and during use
Stiffness	Increase material and pavement structure stiffness
Reflectivity	Increase reflectivity
Concrete Carbon Uptake	Increase uptake
Vehicle Fuel Economy	Improve according to government standards

Buy Clean Policies and Project Delivery

- Develop guidance for states on how to collect and use EPD data
  - Assess current commercial vendors
  - Explore data standards development
  - Emphasize EPDs should be used for material procurement but not material selection
- Develop guidance on establishing benchmarks
- Support use of material carbon budget in lieu of mix specific limits
- Provide incentives to use innovative materials and methods on pilot projects
  - Reduce impediments to performance specifications
  - Industry is willing to take risks and fail when financial backstopping provided
  - Implementing innovation should be accelerated

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