

CONCRETE **INNOVATIONS**

Specifying **Sustainable** Concrete

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June 8, 2022

Calls for net zero commitments are all the rage

UN CLIMATE PRESS RELEASE / 21 SEP, 2020

Commitments to Net Zero Double in Less Than a Year

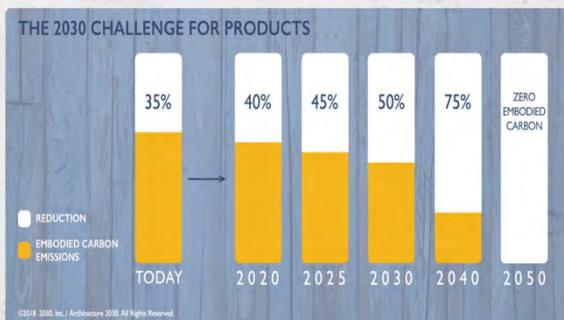
22 regions, 452 cities, 1,101 businesses, 549 universities and 45 of the biggest investors

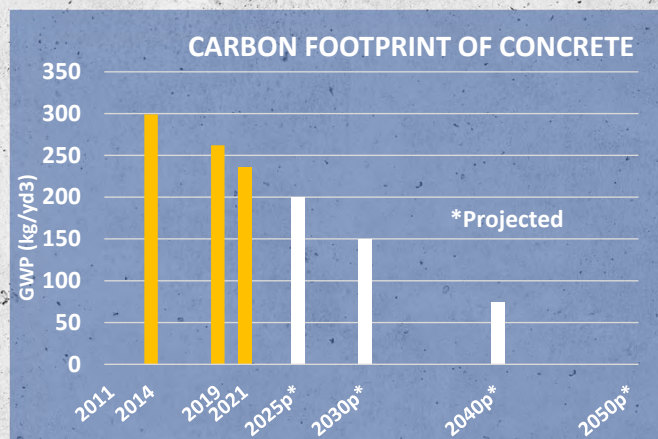
NRMCA Sustainability Initiatives

2009 → 2012 → 2014 → 2016 → 2021



EPD Program Progress

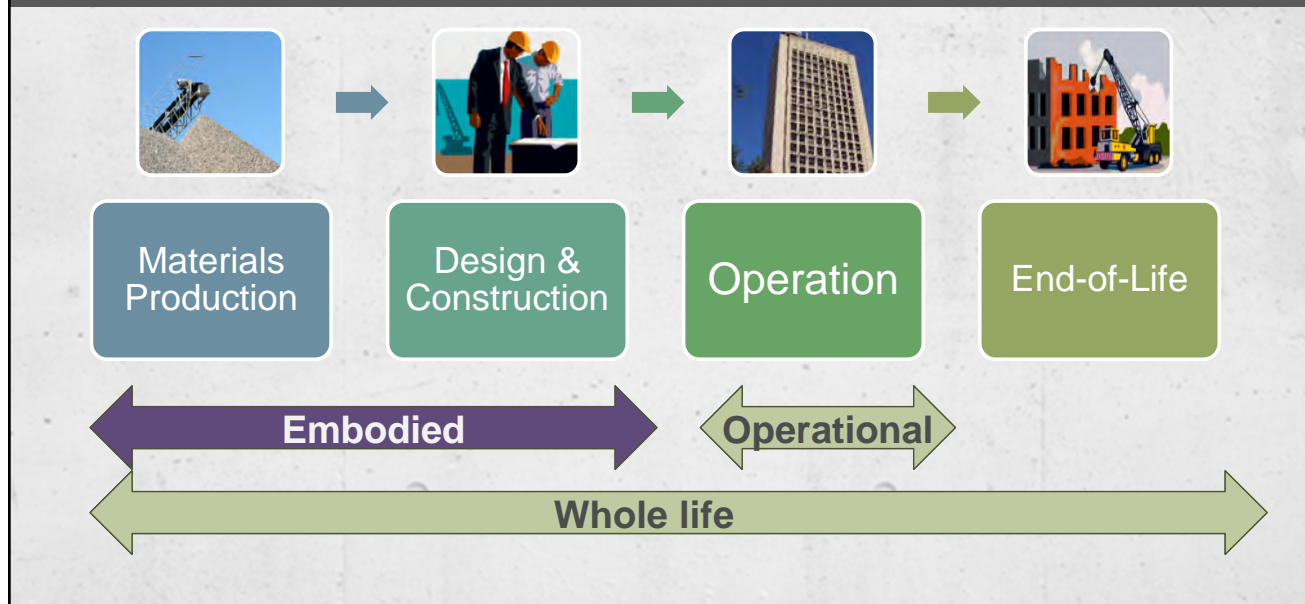
- 21% decrease in embodied CO₂
- 40,000+ concrete EPDs



Green Building Standards & Initiatives



What is embodied vs operational emissions?

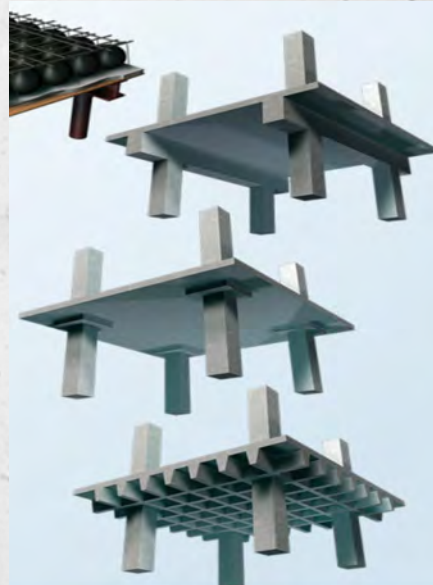
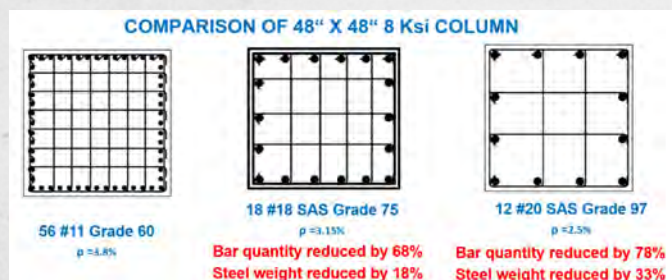


Is Concrete Sustainable?



Influence of Design on Embodied Carbon

- Choice of structural system / grid
- Bay size variations
- Section dimensions
 - Concrete strength
 - Rebar Grade



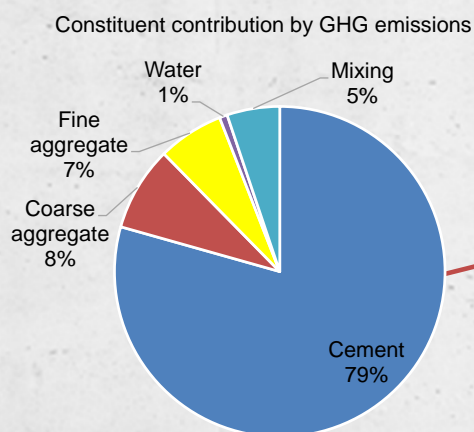
Influence of Project Specifications

- Sustainability criteria should have minimum impact on performance or service life of concrete
- Specifications should not restrict concrete from being sustainable

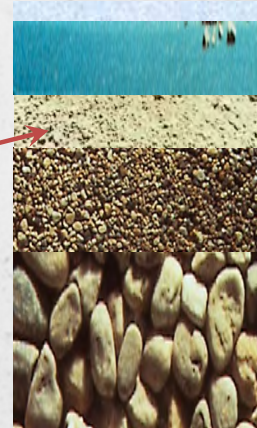


Impact of Specifications for Concrete

- Embodied Carbon (GWP) related to design (specified) strength

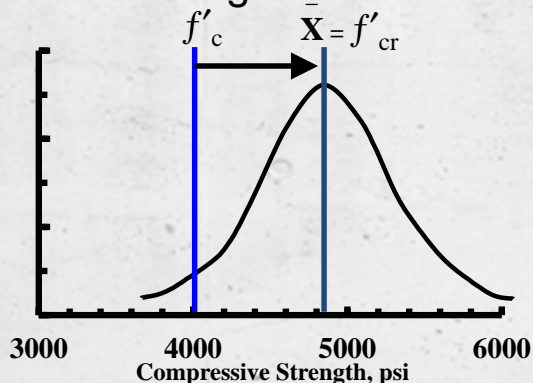


3000 psi mixture with no SCMs



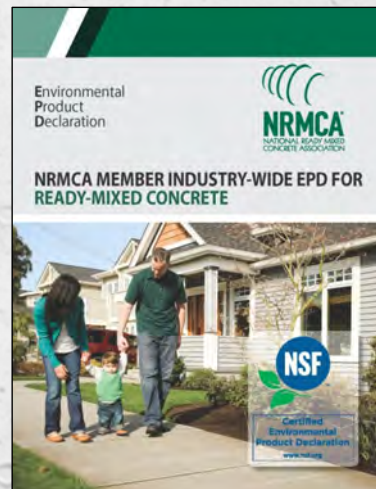
Concrete Strength and Embodied Carbon (GWP)

Specified Strength ▲ **Embodied Carbon** ▲



Average Strength ▲ **Embodied Carbon** ▲

Strength ▲ 100 psi (0.7 MPa) GWP ▲ 1.5%



Sustainable Concrete

- Meet traditional performance requirements of the owner, designers, contractor and producer



- Minimize Energy and Embodied Carbon (GWP)
- Minimize Potable Water Use
- Minimize Waste
- Increase Use of Recycled Content

Is This Concrete Sustainable?

50% portland cement replacement!
Is this Sustainable Concrete?

Portland cement	208 kg/m ³ (300 lb/yd ³)
Slag cement	178 kg/m ³ (300 lb/yd ³)
Silica fume	10 kg/m ³ (50 lb/yd ³)
Coarse aggregate	1068 kg/m ³ (1800 lb/yd ³)
Fine aggregate	712 kg/m ³ (1200 lb/yd ³)
Water	178 kg/m ³ (300 lb/yd ³)
Air content	6%

Not Sure

High Early Strength Concrete



Mass Concrete



Prescriptive Specifications

2.1.2 Water-Cement Ratio

Maximum water-cement ratio (w/c) for concrete shall be 0.40 by weight, for all work.

segregation or bleeding. The cementitious materials content of concrete shall be at least 675 pounds per cubic yard. Except that concrete to be placed by tremie the cementitious materials content shall be at least 725 pounds per cubic yard.

- c. Fly Ash: Fly Ash shall have a high fineness and low carbon content and shall exceed the requirements of ASTM-C-618, "Specification for Fly Ash and Raw or Calcined Natural for Use in Portland Cement Concretes" for Class F, except that the loss of ignition shall be less than 3% and all fly ash shall be a classified processed material. Fly ash shall be obtained from one source for the concrete delivered to the project. Complete chemical and physical analysis of the fly ash shall be submitted to the Architect prior to use. Concrete mixes proportioned with fly ash shall contain not less than 10% nor more than 20% by weight of cement to fly ash.

Most Common Prescriptive Requirements

Prescriptive Requirement	Frequency Seen
Restriction on SCM quantity	85%
Max w/cm (when not applicable)	73%
Minimum cementitious content	46%
Restriction on SCM type, characteristics	27%
Restriction on aggregate grading	25%

References

Prescriptive Specifications

A reality check

by Kathi H. Olson and Chris L. Lobo

ACI Concrete International Aug 2015

Almost a decade ago, the National Ready Mixed Concrete Association (NRMCA) embarked on an effort to evolve specifications for concrete to be more performance-based. The idea of a performance-based specification was to allow the specifier to define the quality of concrete to be used in a project, rather than the quality of materials to be used. The primary goal was to improve the quality of concrete construction, to limit the use of concrete resources, and to improve the performance of concrete structures. The basic principle of the effort is that specifications should recognize the expertise of the concrete producer and the contractor, and not the specifier. The specifier's role is to define the performance requirements for the concrete, and the contractor's role is to provide the materials and methods to achieve those requirements. Prescriptive specifications that describe the details of concrete construction are common in many specifications. Prescriptive specifications that describe the details of concrete construction are common in many specifications. Prescriptive specifications that describe the details of concrete construction are common in many specifications.

Specification in Practice
What, why & how?

SP 1 - Limits on Quantity of Supplementary Cementitious Materials
by Michael J. Jensen

The typical clause restricting the quantity of supplementary cementitious materials (SCMs) in concrete is found in the ACI 308-1R-14 specification. The clause is as follows:

SCM shall not exceed the limits specified in Table 1.1, based on the total cementitious content of the concrete. The limits shall be based on the total cementitious content of the concrete, not on the quantity of cement. The limits shall be based on the total cementitious content of the concrete, not on the quantity of cement. The limits shall be based on the total cementitious content of the concrete, not on the quantity of cement.

Table 1.1: Limits on Quantity of Supplementary Cementitious Materials

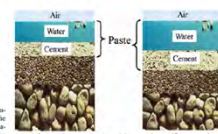
SCM Type	Limit (%)
Pulverized Fuel Ash (PFA)	15
Silica Fume	5
Synthetic Silica Dust	5
Synthetic Silica Fume	5
Synthetic Silica Fume	5

Source: ACI 308-1R-14, Table 1.1.1

structural SPECIFICATIONS

Specifying Requirements for Concrete Mixtures

By John L. Lobo, Ph.D., PE



Technological advances in concrete-making materials, production equipment, and processes have enhanced the performance of concrete in a wide range of applications. Specifications for concrete mixtures, however, continue to be prescriptive, which often limits the ability to develop and use innovative products and construction methods. Specifications should be rewritten to leverage the expertise of the various stakeholders to deliver a high-quality structure with the desired service life to the owner.

The challenges and opportunities with performance-based specifications for concrete have been previously discussed (Lobo et al., STRUCTURE, April 2005). A prescriptive specification is one that includes prescriptive details of materials or means and methods of construction. The intended performance related to a prescriptive specification may or may not be defined. Alternatively, a performance specification defines the needed outcome, tied to acceptance criteria without detailing how it should be achieved. An important principle with performance requirements is the congruence of responsibility and authority. It provides the specific responsibility for the appropriate authority with assigned responsibility to achieve the desired outcome. A prescriptive specification, with a stated or undefined performance outcome, does not. Specifications that combine prescriptive and performance requirements tend to be more problematic.

In a recent evaluation (Lobo et al., 2015), prescriptive requirements that are considered common by concrete producers were noted, and the frequency of these requirements was quantified by performing a sampling of about 100 specifications for different types of structures. Most of these prescriptive requirements are common to concrete mixtures. The American Concrete Institute (ACI) and its

STRUCTURE

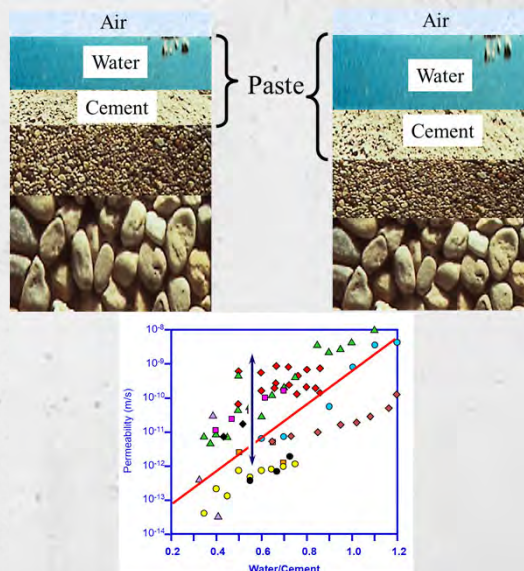
Magazine,

April 2019

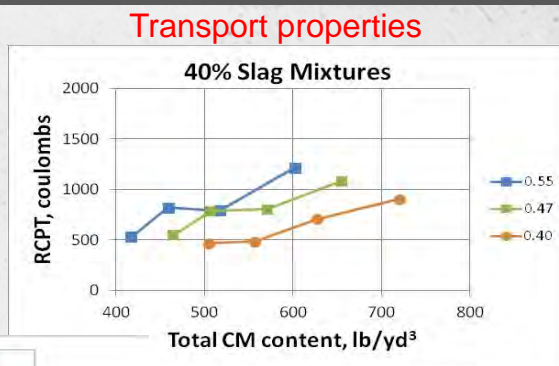
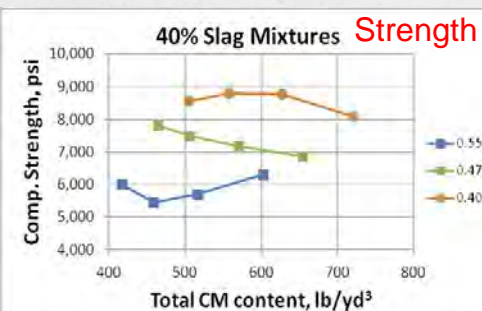
www.structuremag.org

Specifying Water-Cement Ratio

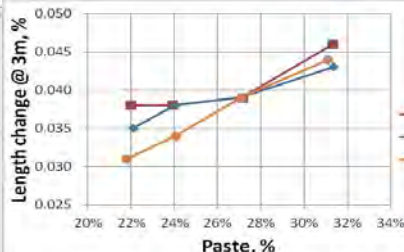
- Paste volume impact
- No “credit” for SCMs
- May not assure intent
- Lower is not always better
 - Impacts sustainability
 - Impacts constructability
 - Associated impact on performance



Effect of CM content



Strength/Workability
Higher Cementitious

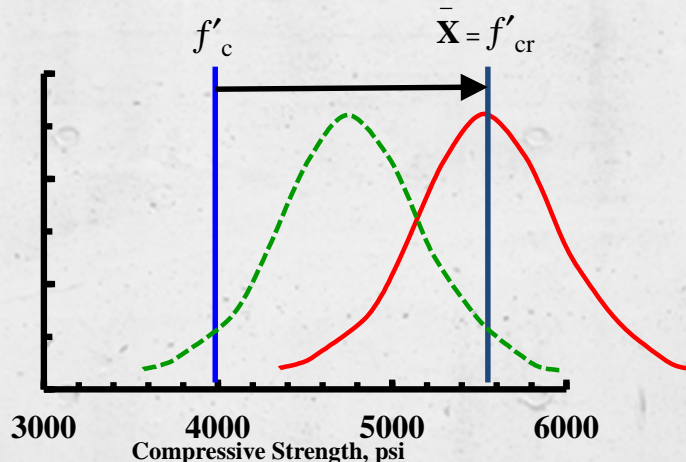


Volume Change

Durability / Cracking
Lower Cementitious

Impact of Prescriptive Specifications

Max w/cm or min cementitious content




Are we Significantly Over-designed?

- Typical “overdesign” $\sim 15\% > f'_c$

w/cm	f'_c	Non Air	Air-Ent
0.40	5000	37%	23%
0.45	4500	34%	21%
0.50	4000	30%	18%
0.55	3500	29%	14%
		33%	19%

Impact of Prescription





**SPECIFYING SUSTAINABLE CONCRETE
(PRINT COURSE)**

Concrete is used in nearly every structure we build today, including buildings, bridges, homes and infrastructure. With ... [READ MORE](#)

AVERAGE RATING
★★★★★

ENROLL

COURSE CREDITS
AIA 1 LU | Elective, PDH Potential 1 Hour,
Canada Potential 1 Learning Credits

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SPECIFYING SUSTAINABLE CONCRETE



INTRODUCTION

Sustainable concrete is difficult to define. There are many factors that can influence the way concrete is manufactured, designed, built, used and recycled that ultimately affect the environmental footprint of the structures built with concrete. Whether one is designing a building, pavement, bridge or dam, concrete is an important management asset for foundation and superstructure, and these structures can have a significant impact on the environment throughout their lifecycles.

Design professionals can influence the performance and environmental impact of structures through effective design and proper specifications. Regardless of the materials being used, however, concrete is unique in that it is an integral part of many of the most important structures, including bridges, dams, highways, and other infrastructure. Concrete's strength, durability, and appearance are key factors in its selection for many applications. Additionally, concrete's low embodied carbon footprint and its ability to be recycled at the end of its life make it a sustainable choice for many applications.

LEARNING OBJECTIVES

1. Identify the difference between performance-based specification and prescriptive specification.
2. Understand the importance of specifying concrete performance and prescriptive specifications.
3. Understand the importance of specifying concrete performance and prescriptive specifications.
4. Understand the importance of specifying concrete performance and prescriptive specifications.

CONTINUING EDUCATION

AIA 1 LU | Elective, PDH Potential 1 Hour, Canada Potential 1 Learning Credits

Ref: Lemay, Lobo, Obla, Hanley Wood University, 2019

www.nrmca.org/sustainability

Impact of Prescription

Specification Provision	Impact of provision		
	Sustainability	Performance	Cost
Restrictions on characteristics of aggregates	↓	↔	↑
Invoking a minimum content for cementitious materials	↓	↕	↑
Prescriptive requirements toward green building credit	↑	↕	↕
Restriction on SCM characteristics	↓	↓	↑
Restriction on quantity of SCM	↓	↓	↑

Ref: Lemay, Lobo, Obla, Hanley Wood University, 2019

Impact of Prescription

Table 1. Impact of Prescriptive Specification on Sustainability, Performance and Cost

Specification Provision	Impact		
	Sustainability	Performance	Cost
1. Restrictions on type and source of cement	↓	↕	↑
2. Not permitting cements conforming to ASTM C1157 and ASTM C595	↓	↔	↔
3. Restriction on cement alkali content	↓	↔	↑
4. Restriction on type and source of aggregates	↓	↔	↑
5. Restrictions on characteristics of aggregates	↓	↔	↑
6. Minimum content for cementitious materials	↓	↕	↑
7. Restriction on quantity of SCM	↓	↓	↑
8. Restriction on type and characteristics of SCM	↓	↓	↑
9. Restriction on type or brands of admixtures	↔	↓	↑
10. Same class of concrete for all members in a structure	↓	↔	↑
11. Requiring higher strength than required for design	↓	↔	↑
12. Invoking maximum w/cm when not applicable or one that is not compatible with the design/specified strength.	↓	↔	↑
13. Requiring a high air content or requiring air content for concrete not exposed to freezing and thawing	↓	↓	↑
14. Restricting the use of a test records for submittals	↓	↓	↑
15. Restriction on changing proportions when needed to accommodate material variations and ambient conditions	↓	↓	↑
16. Requirement to use potable water	↓	↕	↑
17. Not permitting recycled aggregates and materials	↓	↕	↕
18. Not requiring accredited testing labs	↓	↔	↑
19. Specific limitations on slump	↓	↓	↕

7. Quantity of SCM: Some specifications place limits on the quantity of SCMs. Often, the use of more than one type of SCM is prohibited. This prevents optimizing concrete mixtures for performance and durability. The only building code restriction is for exterior concrete subject to application of deicing chemicals. Maximum limits on the quantity of SCM increases cost and does not support sustainable development. Increasingly, projects seeking green certification impose prescriptive requirements on concrete mixtures such as minimum replacement for cement or minimum recycled content. These requirements can often impact the performance of fresh and hardened concrete properties, such as setting characteristics, ability to place and finish and rate of development of in-place properties. In the long run, this may impact the quality of construction or the service life of the structure. The implication to initial cost may be reduced, but it could cost more in the long term. Alternatives to limiting quantities of SCM to lower environmental impact are discussed later.

To Achieve Optimized Performance

- Quality of paste
 - Supplementary cementitious materials
 - Admixtures
- Quantity of paste - minimize
 - Cementitious materials
 - Control of water
 - Aggregate grading
- Improved Quality Control
- Specific durability issues – ASR, sulfate resistance
- Constructability



Strength
Permeability



Shrinkage
Thermal effects
Permeability

The specification should not restrict achieving these goals

Performance Alternatives

- Permeability
 - RCP - ASTM C1202 (1500 coulombs?)
 - Bulk resistivity - ASTM C1876 (120 ohm.m?)
 - Surface resistivity - AASHTO T 358
- Shrinkage
 - ASTM C157 (0.05%)
 - Define specimen size; duration of curing and drying
- ASR – ASTM C1293; ASTM C1567

ACI 318-19 – Durability Requirements

Chapter 19

19.3.1.1

19.3.1 Exposure categories and classes

19.3.1.1 The licensed design professional shall assign exposure classes in accordance with the severity of the anticipated exposure of members for each exposure category in Table 19.3.1.1.

The **licensed design professional shall assign** exposure classes in accordance with the severity of the **anticipated exposure** of members **for each exposure category** according to Table 19.3.1.1

Exposure Categories Durability (ACI 318)

Table 19.3.2.1—Requirements for concrete by exposure class

Exposure class	Maximum w/cm ^{(1),(2)}	Minimum f _c , psi	Additional requirements	Limits on cementitious materials			
F0	N/A	2500	Air content	N/A			
F1	0.55	3500	Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete	N/A			
F2	0.45	4500	Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete	N/A			
F3	0.40 ⁽³⁾	5000 ⁽³⁾	Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete	26.4.2.2(b)			
			Cementitious materials ⁽⁴⁾ — Types	Calcium chloride admixture			
			ASTM C150	ASTM C595	ASTM C1157		
S0	N/A	2500	No type restriction	No type restriction	No type restriction	No restriction	
S1	0.50	4000	III ⁽⁵⁾⁽⁶⁾	Types with (MS) designation	MS	No restriction	
S2	0.45	4500	V ⁽⁶⁾	Types with (HS) designation	HS	Not permitted	
S3	Option 1	0.45	4500	V plus pozzolan or slag cement ⁽⁷⁾	Types with (HS) designation plus pozzolan or slag cement ⁽⁷⁾	HS plus pozzolan or slag cement ⁽⁷⁾	Not permitted
	Option 2	0.40	5000	V ⁽⁸⁾	Types with (HS) designation	HS	Not permitted
			None				
W0	N/A	2500					
W1	N/A	2500	26.4.2.2(d)				
W2	0.50	4000	26.4.2.2(d)				
			Maximum water-soluble chloride ion (Cl ⁻) content in concrete, percent by mass of cementitious materials ^{(9),(10)}				
			Nonprestressed concrete	Prestressed concrete		Additional provisions	
C0	N/A	2500	1.00	0.06		None	
C1	N/A	2500	0.30	0.06			
C2	0.40	5000	0.15	0.06		Concrete cover ⁽¹¹⁾	

Requirements for Concrete (partial)

Concrete Mixtures				
Members	Exposure	f _c load/dur	w/cm	NMSA
Pool and deck	F2, S0, W1, C1	4,000 / 4,500	0.45	¾-in.
Interior slabs and beams	F0, S0, W0, C0	4,000 / n/a	n/a	¾-in.
Interior columns	F0, S0, W0, C0	8,000 / n/a	n/a	¾-in.
Balconies	F3, S0, W0, C2	4,000 / 5,000	0.40	¾-in.
Exterior walls	F1, S0, W0, C1	3,500 / 3,500	0.55	1-in.
Foundation	F0, S1, W0, C1	3,000 / 4,000	0.50	1-in.
Parking Slabs	F0, S1, W0, C2	3,000 / 5,000	0.40	¾-in.

- Specify Exposure Class (ACI 318)
- Can test age >28 days?
- Performance criteria (permeability, shrinkage, etc.)

Evolution to Performance

- Identify Exposure Classes

Member	Mix ID	Durability Exposure				Specified Strength, f'_c , psi	Max w/cm or Performance Alternative	Nom. max Aggregate, in.	Air Content	Slump/ Slump Flow	Chloride Limit	Temp. Limits
		F	S	W	C							
Footings												
Foundation Walls												
Slabs-on-grade												
Exterior slabs												
Suspended slabs (interior)												
Suspended slabs (exterior)												
Frame members												
Columns (interior)												
Columns (exterior)												
Walls (interior)												
Concrete toppings												

31

Evolution to Performance

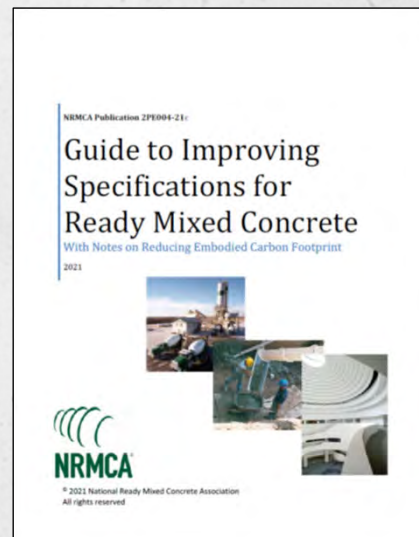
- Performance requirements as applicable

Member	RCP, C1202	Shrinkage, C157	Freeze Thaw		ASR	MOE, C469	Thermal Control Plan	Density	Other
			C666	C457					
Footings					X				
Foundations					X		X		
Slabs on Grade		X			X				
Exterior Slabs	X		X						
Interior Slabs		X						X (LW)	
Frame Members						X			
Interior Columns						X			
Exterior Columns									
Interior Walls									
Exterior Walls					X				
Slab Toppings					X				

Specifications for Sustainability

General Guidelines

- Address prescriptive limits
- Do not restrict use of materials
 - Blended cements
 - SCMs and admixtures
 - Recycled materials
- Avoid specifying means and methods
- Address performance requirements
 - By application
- Consider innovation



www.nrmca.org/sustainability

Factors Impacting Strength / GWP

Increases Strength & GWP

- Prescriptive requirements
- Early age strength
- Quality control
 - standard deviation
 - overdesign
- Quality Assurance
 - acceptance testing

Decrease GWP @ target strength

- Paste volume
- Use of SCMs / admixtures
- Later strength age requirement

Designer

- Optimizing design
- Use anticipated strength to advantage

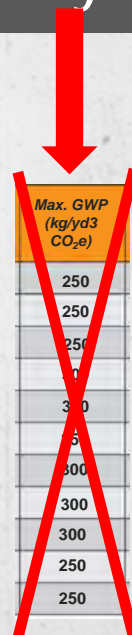
Factors Impacting Embodied Carbon

- Typically higher
 - Early strength – PT, formwork removal
 - Self-consolidating concrete
 - Workability for Placement
 - Slabs – finishing
 - Higher air content
- Can be lower
 - Later age strength
 - Mass concrete
 - Performance-based – shrinkage, permeability, modulus...

Specifications for Sustainability

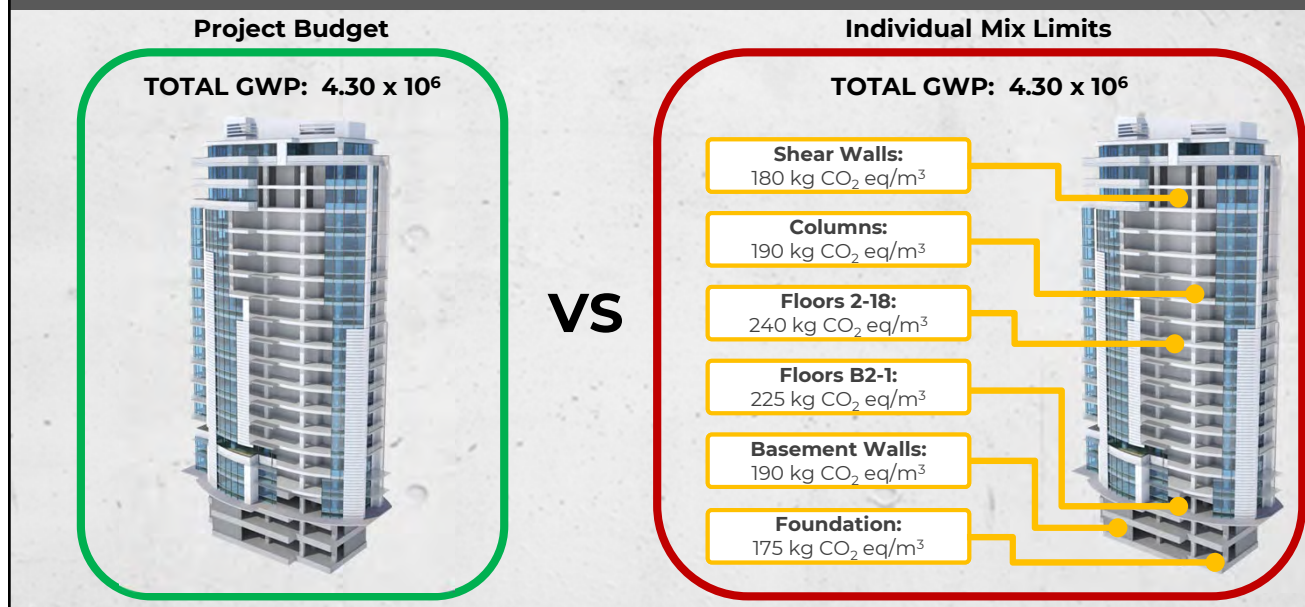
- Avoid GWP limits for each mixture
- Establish carbon budget for all concrete
 - Percent reduction from benchmark OR Max GWP for all concrete

Member	Mix ID	Durability Exposure				Specified Strength, f'_c , psi	Max w/cm or Performance Alternative	Nom. max Aggregate, in.	Air Content	Slump/Slump Flow	Chloride Limit	Temp. Limits
		F	S	W	C							
Footings												
Foundation Walls												
Slabs-on-grade												
Exterior slabs												
Suspended slabs (interior)												
Suspended slabs (exterior)												
Frame members												
Columns (interior)												
Columns (exterior)												
Walls (interior)												
Concrete toppings												

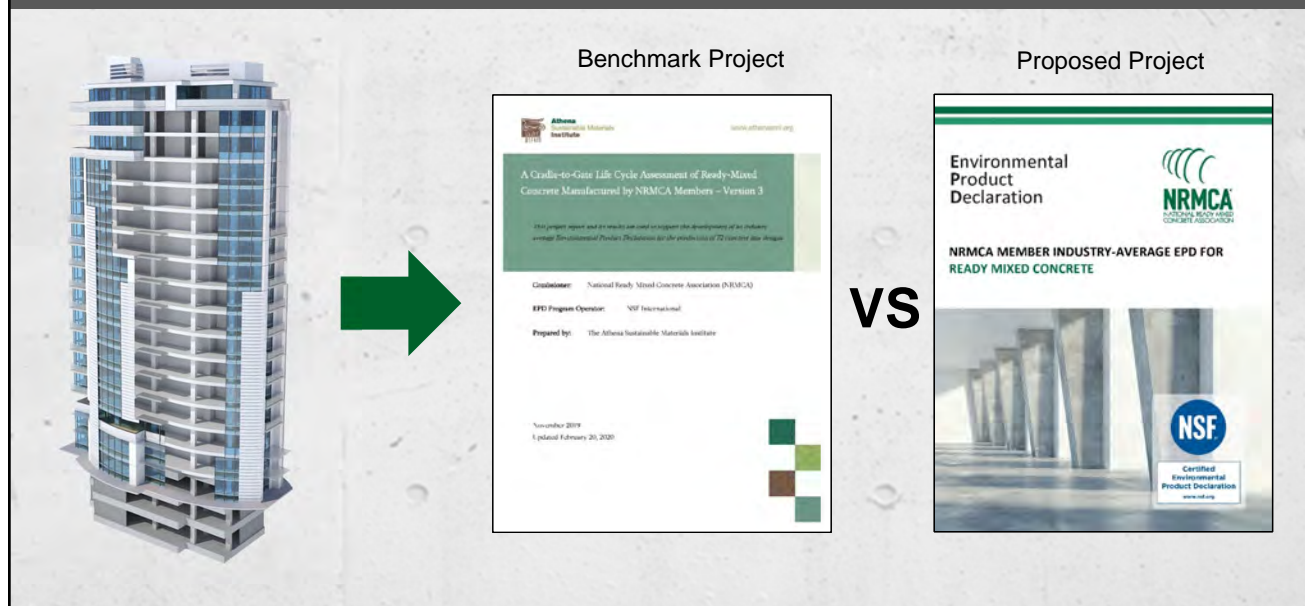


36

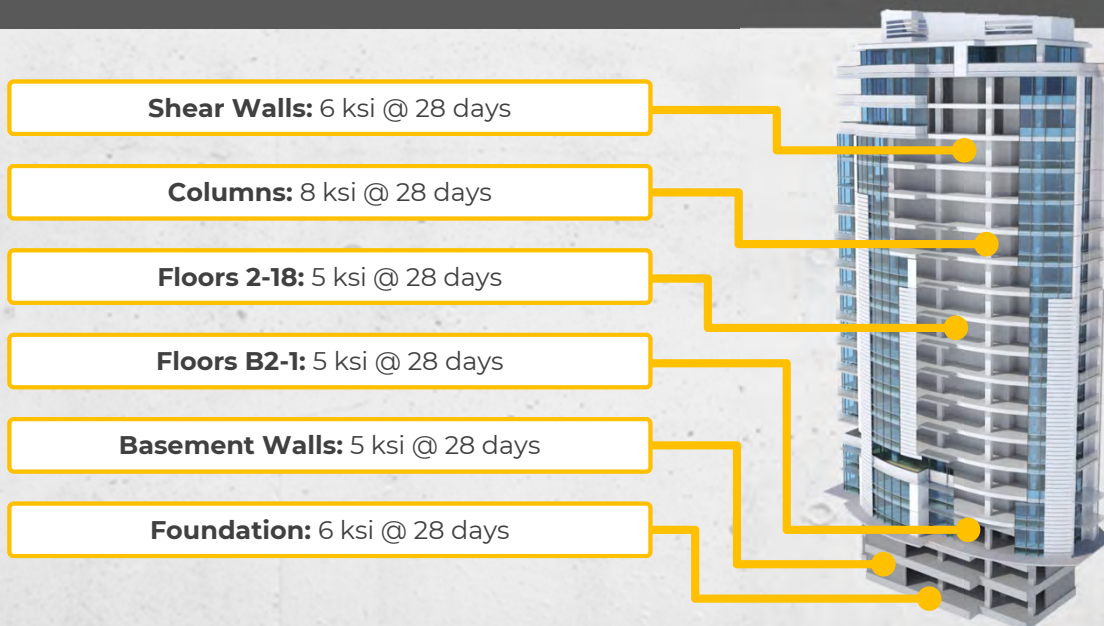
Establishing a Carbon Budget



Establishing a Carbon Budget



Example: Proposed Building in Northeast U.S.

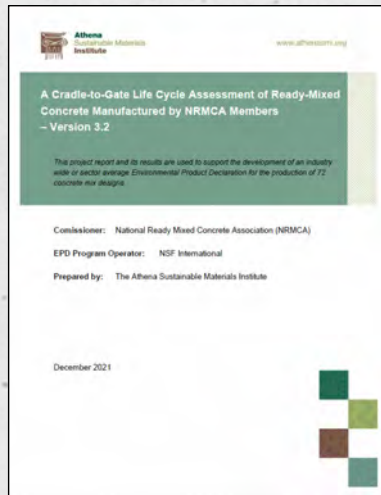


Estimating Quantities and Properties of Concrete

Concrete Element	Concrete Volume (yd ³)	Benchmark Mixes (benchmark)*	Proposed Mixes (IW-EPD)*
Shear Walls	7,630	6,000 psi	6,000 psi 30% slag, 20% fly ash
Columns	366	8,000 psi	8,000 psi 40% fly ash
Floors 2-18	4,533	5,000 psi	5,000 psi 30% slag
Floors B2-1	1,067	5,000 psi	5,000 psi 40% fly ash
Basement Walls	444	5,000 psi	5,000 psi 40% slag, 30% fly ash
Foundation	2,844	6,000 psi	6,000 psi 40% slag, 30% fly ash

*Should be augmented with local data, knowledge, capabilities

NRMCA Benchmark Mixes



These Concrete Mixes are defined:

Table 1: NRMCA U.S. Benchmark Production Data Summary

Concrete Mix Design	Volume (m³)	Weight (kg)	Volume (m³)	Weight (kg)
1	1.00	2400	1.00	2400
2	1.00	2400	1.00	2400
3	1.00	2400	1.00	2400
4	1.00	2400	1.00	2400
5	1.00	2400	1.00	2400
6	1.00	2400	1.00	2400
7	1.00	2400	1.00	2400
8	1.00	2400	1.00	2400
9	1.00	2400	1.00	2400
10	1.00	2400	1.00	2400
11	1.00	2400	1.00	2400
12	1.00	2400	1.00	2400
13	1.00	2400	1.00	2400
14	1.00	2400	1.00	2400
15	1.00	2400	1.00	2400
16	1.00	2400	1.00	2400
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33	1.00	2400	1.00	2400
34	1.00	2400	1.00	2400
35	1.00	2400	1.00	2400
36	1.00	2400	1.00	2400
37	1.00	2400	1.00	2400
38	1.00	2400	1.00	2400
39	1.00	2400	1.00	2400
40	1.00	2400	1.00	2400
41	1.00	2400	1.00	2400
42	1.00	2400	1.00	2400
43	1.00	2400	1.00	2400
44	1.00	2400	1.00	2400
45	1.00	2400	1.00	2400
46	1.00	2400	1.00	2400
47	1.00	2400	1.00	2400
48	1.00	2400	1.00	2400
49	1.00	2400	1.00	2400
50	1.00	2400	1.00	2400
51	1.00	2400	1.00	2400
52	1.00	2400	1.00	2400
53	1.00	2400	1.00	2400
54	1.00	2400	1.00	2400
55	1.00	2400	1.00	2400
56	1.00	2400	1.00	2400
57	1.00	2400	1.00	2400
58	1.00	2400	1.00	2400
59	1.00	2400	1.00	2400
60	1.00	2400	1.00	2400
61	1.00	2400	1.00	2400
62	1.00	2400	1.00	2400
63	1.00	2400	1.00	2400
64	1.00	2400	1.00	2400
65	1.00	2400	1.00	2400
66	1.00	2400	1.00	2400
67	1.00	2400	1.00	2400
68	1.00	2400	1.00	2400
69	1.00	2400	1.00	2400
70	1.00	2400	1.00	2400
71	1.00	2400	1.00	2400
72	1.00	2400	1.00	2400

These Concrete Mixes are defined:

Table 2: NRMCA U.S. Benchmark Life Cycle Data (per m³)

Concrete Mix Design	Volume (m³)	Weight (kg)	Volume (m³)	Weight (kg)
1	1.00	2400	1.00	2400
2	1.00	2400	1.00	2400
3	1.00	2400	1.00	2400
4	1.00	2400	1.00	2400
5	1.00	2400	1.00	2400
6	1.00	2400	1.00	2400
7	1.00	2400	1.00	2400
8	1.00	2400	1.00	2400
9	1.00	2400	1.00	2400
10	1.00	2400	1.00	2400
11	1.00	2400	1.00	2400
12	1.00	2400	1.00	2400
13	1.00	2400	1.00	2400
14	1.00	2400	1.00	2400
15	1.00	2400	1.00	2400
16	1.00	2400	1.00	2400
17	1.00	2400	1.00	2400
18	1.00	2400	1.00	2400
19	1.00	2400	1.00	2400
20	1.00	2400	1.00	2400
21	1.00	2400	1.00	2400
22	1.00	2400	1.00	2400
23	1.00	2400	1.00	2400
24	1.00	2400	1.00	2400
25	1.00	2400	1.00	2400
26	1.00	2400	1.00	2400
27	1.00	2400	1.00	2400
28	1.00	2400	1.00	2400
29	1.00	2400	1.00	2400
30	1.00	2400	1.00	2400
31	1.00	2400	1.00	2400
32	1.00	2400	1.00	2400
33	1.00	2400	1.00	2400
34	1.00	2400	1.00	2400
35	1.00	2400	1.00	2400
36	1.00	2400	1.00	2400
37	1.00	2400	1.00	2400
38	1.00	2400	1.00	2400
39	1.00	2400	1.00	2400
40	1.00	2400	1.00	2400
41	1.00	2400	1.00	2400
42	1.00	2400	1.00	2400
43	1.00	2400	1.00	2400
44	1.00	2400	1.00	2400
45	1.00	2400	1.00	2400
46	1.00	2400	1.00	2400
47	1.00	2400	1.00	2400
48	1.00	2400	1.00	2400
49	1.00	2400	1.00	2400
50	1.00	2400	1.00	2400
51	1.00	2400	1.00	2400
52	1.00	2400	1.00	2400
53	1.00	2400	1.00	2400
54	1.00	2400	1.00	2400
55	1.00	2400	1.00	2400
56	1.00	2400	1.00	2400
57	1.00	2400	1.00	2400
58	1.00	2400	1.00	2400
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63	1.00	2400	1.00	2400
64	1.00	2400	1.00	2400
65	1.00	2400	1.00	2400
66	1.00	2400	1.00	2400
67	1.00	2400	1.00	2400
68	1.00	2400	1.00	2400
69	1.00	2400	1.00	2400
70	1.00	2400	1.00	2400
71	1.00	2400	1.00	2400
72	1.00	2400	1.00	2400

Download at <https://www.nrmca.org/association-resources/sustainability/epd-program/>

Environmental Product Declaration (EPD)

3rd party verified & registered documents that communicate transparency

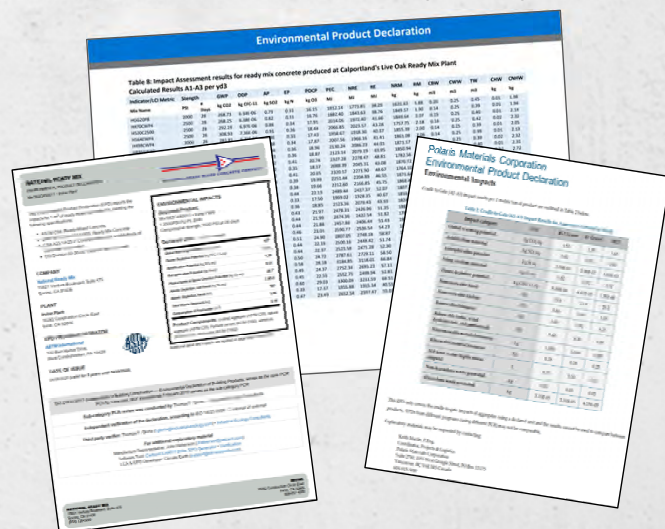
ENVIRONMENTAL IMPACTS

Declared Product:
Mix 2EFZG82Z • San Francisco Plant 30 Plant
Description: 2IN LN 0.45 W/C 3/8" EF70 5-TSL CO2
Compressive strength: 4000 PSI at 28 days

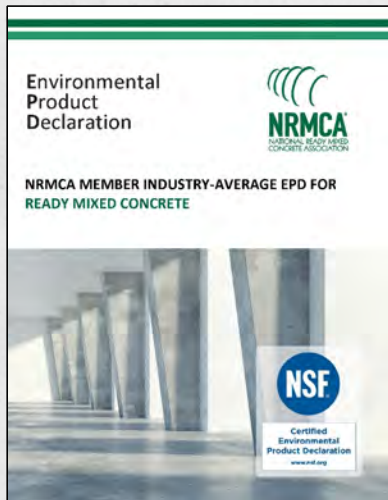
Declared Unit: 1 m³ of concrete

Global Warming Potential (kg CO ₂ -eq)	190
Ozone Depletion Potential (kg CFC-11 eq)	0.35E-6
Acidification Potential (kg SO ₂ -eq)	1.99
Eutrophication Potential (kg N-eq)	0.16
Photochemical Ozone Creation Potential (kg O ₃ -eq)	36.6
Abiotic Depletion, non-fossil (kg So-eq)	4.12E-5
Abiotic Depletion, fossil (MJ)	1,393
Total Waste Disposed (kg)	0.27
Consumption of Freshwater (m³)	1.69

Product Components: natural aggregate (ASTM C33), slag cement (ASTM C989), Portland cement (ASTM C150), fly ash (ASTM C618), batch water (ASTM C1602), admixture (ASTM C494)



NRMCA Proposed Industry Wide EPD Mixes

[illegible]

Environmental Product Declaration

Table 1: Concrete Product Rapid Quantification Checklist

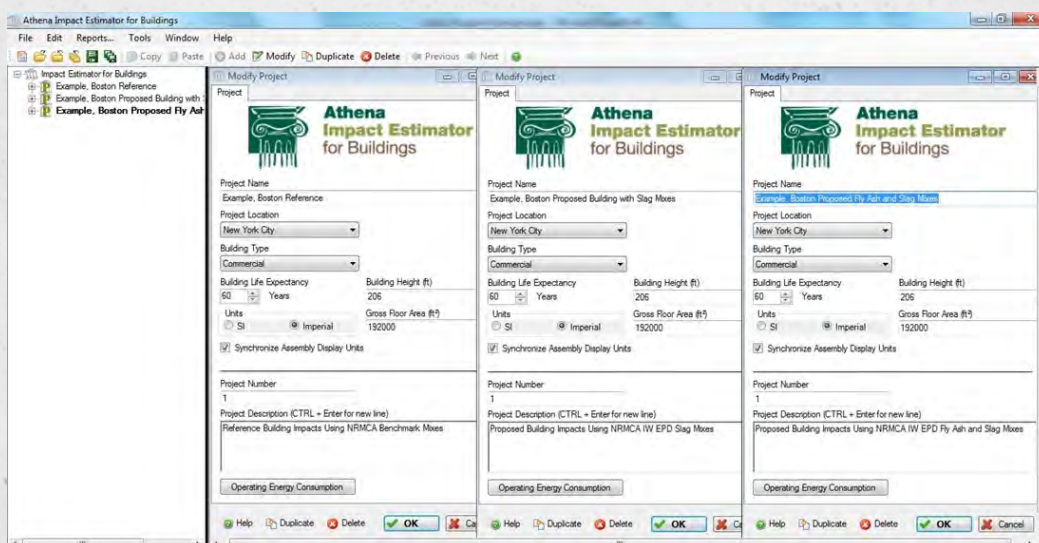
CEM I 42.5/N	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM II 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM III 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM IV 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM V 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM VI 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM VII 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM VIII 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM IX 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM X 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XI 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XII 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XIII 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XIV 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XV 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XVI 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XVII 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XVIII 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XIX 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XX 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XXI 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XXII 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XXIII 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XXIV 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XXV 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XXVI 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XXVII 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XXVIII 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XXIX 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%
CEM XXX 42.5/N	0% 0% 0%	0% 0% 0%	0% 0% 0%
100% 100%	100% 100% 100%	100% 100% 100%	100% 100% 100%

Product Manual

Products covered by this EPD serve general purpose concrete or used in residential, commercial and public-utility applications in the US and Canada. This EPD supports the approach for a range of widely used concrete products in accordance with the following:

Download at <https://www.nrmca.org/association-resources/sustainability/epd-program/>

Athena Impact Estimator (includes NRMCA mixes)



Defining Benchmark and Proposed Project in Athena IE

**Reference Mixes
(benchmark)**

#	ID	Name	Amount	Construction Waste Factor	Net Amount	Unit
1001	251	Concrete Benchmark 5000 psi	6,544.00	0.00	6,544.00	yd ³
1002	252	Concrete Benchmark 4000 psi	10,474.00	0.00	10,474.00	yd ³
1003	253	Concrete Benchmark 3000 psi	366.00	0.00	366.00	yd ³

**Proposed Project
Mixes (IW-EPD)**

#	ID	Name	Amount	Construction Waste Factor	Net Amount	Unit
1004	100001	5000-30FA-00SL	444.00	0.00	444.00	yd ³
1005	100002	4000-20FA-00SL	2,844.00	0.00	2,844.00	yd ³
1006	100003	3000-10FA-00SL	4,533.00	0.00	4,533.00	yd ³
1007	100004	2000-05FA-00SL	1,067.00	0.00	1,067.00	yd ³
1008	100005	1000-02FA-00SL	7,630.00	0.00	7,630.00	yd ³

Final Results

Project	GWP (kg/yd ³)	GWP Reduction
Benchmark Mixes	6.14 x 10 ⁶	0
Proposed with Fly Ash and Slag Mixes	3.92 x 10 ⁶	-36%
Establish Carbon Budget	4.30 x 10 ⁶	-30%*

* ~5% tolerance should be achievable

Proposed Specification Language

Option 1

Supply concrete mixtures such that the total Global Warming Potential (GWP) of all concrete on the project is **less than or equal to 4,300,000 kg of CO₂ equivalents** as calculated using the Athena Impact Estimator for Buildings Software available at www.athenasmi.org.

Option 2

Supply concrete mixtures such that the total Global Warming Potential (GWP) of all concrete on the project is **30% or more below the GWP of a benchmark building** using Benchmark mixes as established by NRMCA and available for download at www.nrmca.org. Submit a summary report of all the concrete mixtures, their quantities and their GWP to demonstrate that the total GWP of the building is 30% or more below the GWP of the benchmark project. Contractor may use the Athena Impact Estimator for Buildings software available at www.athenasmi.org or other similar software with the capability of calculating GWP of different mix designs.

Summary

- Carbon Footprint Reduction
 - Minimize prescriptive limits
 - Performance-based requirements
 - Permit innovative products and processes
- Define project goals for sustainability
- Communicate and partner early with all project stakeholders
 - Consider potential impact on cost



CONCRETE INNOVATIONS

Questions?

**Specifying
Sustainable Concrete**

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