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NRMCA'S 2024 CONCRETEWORKS
DENVER, CO | OCTOBER 10 - 14

Specifications for Performance & Sustainability

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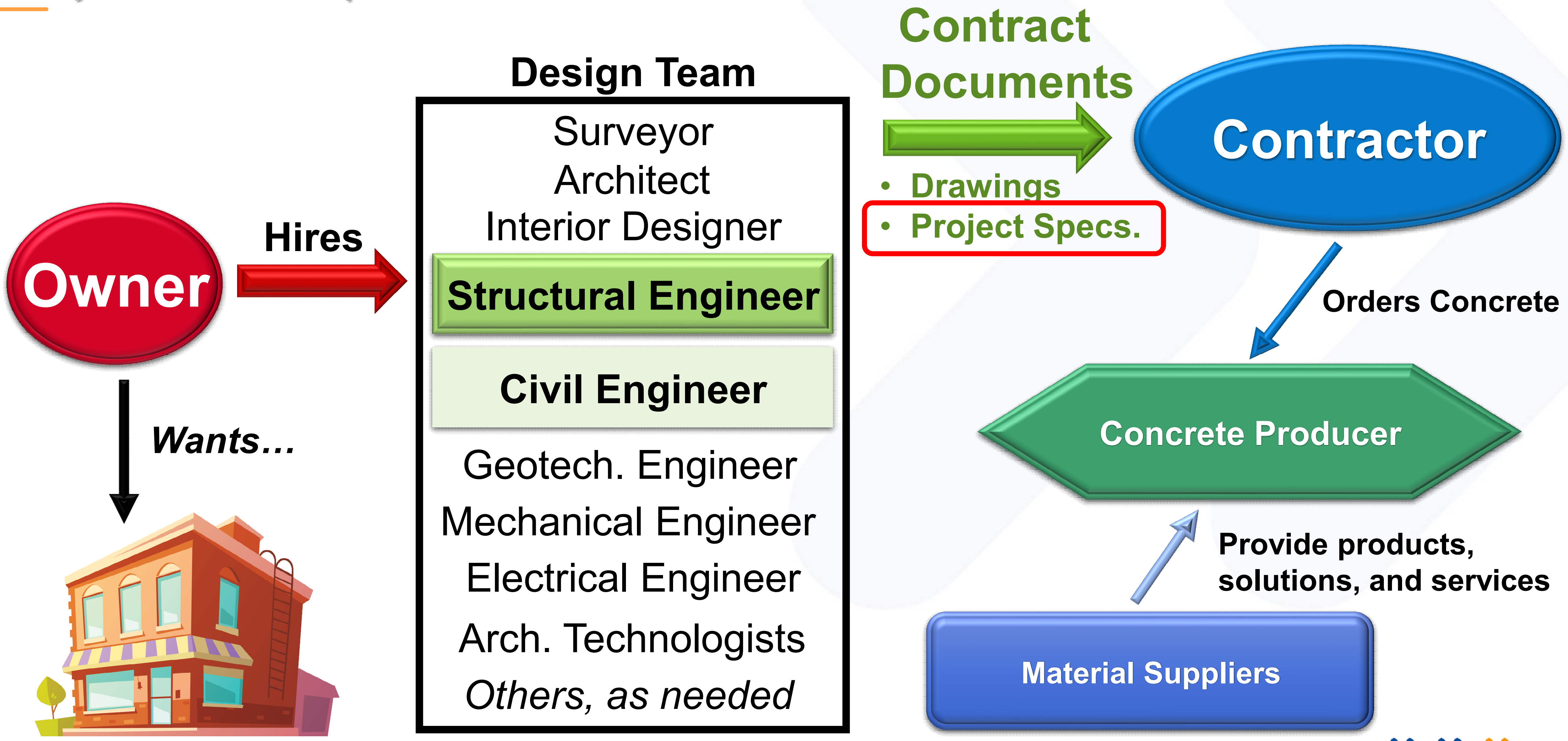
Outline

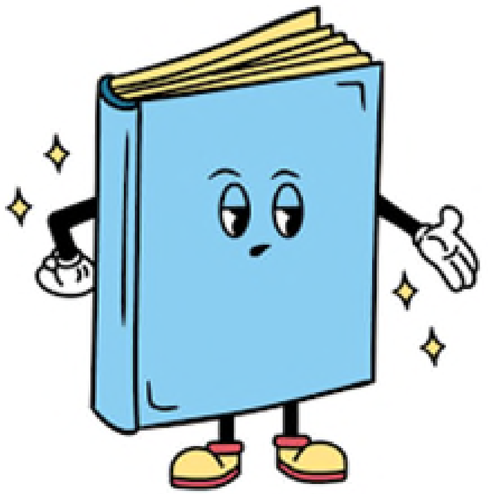
1. Review of Types of Construction Specifications
2. Durability & Sustainability of Concrete
3. LECC – Challenges & Opportunities
4. Summary / Questions

Project Delivery… The Value Chain



Types of Construction Specifications

- Prescriptive
- Performance
- Proprietary



Types of Construction Specifications: Prescriptive

Part 1 General

- Provides an introduction, defines key terms, outlines the scope of work, and specifies submission guidelines and quality assurance standards.

Part 2 Products

- Provides information about the materials, equipment, and products that will be used in the project.

Part 3 Execution

- Describes the installation or application protocols, including preparation, examination, installation, and confirmation of performance standards.

The **CSI 3-Part Specifications** are contract documents that **define the quality of Work Results** for a construction project.

Types of Construction Specifications: Performance

- Addresses operational requirements of an installation.
- Focus is on the project outcome, indicating how the final project must be able to function.
  - **Architect**
    - Provides guidance to general contractor
    - Limited authority during construction
  - **General Contractor**
    - Determines best path to achieve the desired outcome
    - Flexibility

Types of Construction Specifications: Performance

"A specification in which the requirements are stated in terms of required results with criteria for verifying compliance rather than specific composition, design, or procedure."

ACI CT-23

Types of Construction Specifications: Proprietary

- Demands the use of only one specific product for a given installation.
- Used if the portion of a project requires a certain performance that only one product can achieve.
- Can drive up project costs!

Product A ✓

Types of Construction Specifications: “Open” or “Closed”

Open:

- Specifier does not name a specific supplier or product.
- Dictated by set of standards that more than one manufacturer can meet.
  - Does not limit competition.
  - Permits submittal of many alternatives for approval.
  - Allows for substitutions to be made by the contractor.

Ex. Performance Specification

Closed:

- Lists specific products, systems & manufacturers.
- Typically used when matching a spec to an existing structure, or when an exact duplicate is required.
- No alternatives or mechanisms to apply a substitution.
- Can be made “open” by adding “or equal.”

Ex. Proprietary Specification

Time for Reflection…

BUILDING NO.
PROJECT NAME

SC#

F. Aggregate for Standard Weight Concrete: ASTM C33, except as modified herein.
   1. Coarse Aggregates: Cleanness Value of not less than 75 when tested as per CMM-Test Method No. California 227.
   2. Coarse Aggregate for Shrinkage Controlled Concrete: [redacted] (as supplied by [redacted]
   3. Fine Aggregates: Sand Equivalent of not less than 75 when tested per CMM-Test Method No. California 217.

G. Aggregate for Lightweight Concrete: ASTM C330. Lightweight aggregate shall be vacuum saturated expanded shale or clay produced by rotary kiln.

H. Water: Mixing water shall be clean, potable and free from deleterious material.

I. Admixtures
   1. General:
      a. Admixtures containing more than 0.05 percent chloride ions are not permitted.
      b. Where mix contains more than one admixture, all admixtures shall be supplied by one manufacturer. Manufacturer shall certify that admixtures are compatible such that desirable effects of each admixture will be realized.
      c. Liquid admixtures shall be considered part of the total water.

- Prescriptive?
- Performance??
- Proprietary???

J. Lightweight Concrete shall contain an air entrainment admixture conforming to ASTM C260, to produce an air content of 3 to 5 percent at point of placement.

K. Water Reducing Admixture: ASTM C494, Type A. Provide in all concrete at necessary dosage to facilitate placement.

L. Mid to High Range Water Reducing Admixture: ASTM C494, Type F; polycarboxylate formulation. Provide in mid-range or high-range dosage as necessary for placement at the maximum water to cement ratio specified.

M. Set Accelerating Admixture: ASTM C494, Type E, non-chloride. Subject to approval of University's Representative, provide in necessary dosage to accelerate set.

N. Set Retarding Admixture: ASTM C494, Type D. Subject to approval of University's Representative, provide in necessary dosage to retard set.

O. Color Admixtures: ASTM C579; products of [redacted], or equal. Provide color as approved by the University's Representative from job site samples. Exposed exterior concrete shall contain 2 pounds [redacted] per cubic yard.

Prescriptive- vs. Performance-Based Concrete Specifications

Prescriptive:

- Defines a concrete mixture in terms of its constituents and their proportions.
- **A means to an end…**
  - Minimum cementitious materials content
  - Maximum w/cm
  - Air content
  - Slump
  - **Verified**

Performance:

- Defines a concrete mixture in terms of measurable plastic and hardened properties.
  - Does the concrete mixture satisfy the specified performance criteria?
- **The end is verified by measuring the specific concrete properties**.
  - Sampling from either the truck chute (or point of placement)
  - Ideally, in-place.
- Test methods and acceptance criteria must be clearly defined!

Prescriptive- vs. Performance-Based Concrete Specifications

Who is Responsible for the Project's End Result?

- **Prescriptive:** →→ Owner / Owner's Reps
- **Performance:** →→ Contractor / Subs

Hybrid?

Request for Information (RFI) Process is at Your Disposal

- A formal, written process commonly used to clarify or request information about a construction project.
  - Plans
  - Specifications
  - Other Contract Documents

- Use if following the plans or specifications may not satisfy the owner's performance expectations.

Use RFIs if specification requirements are unclear!

https://www.bigrentz.com/blog/what-is-an-rfi

Request for Information (RFI) Process is at Your Disposal

August 28, 2024

Request for Information.

Project: **A Project in Hawaii**

SECTION 03300 - CAST-IN-PLACE CONCRETE

2.04 CONCRETE MATERIALS

A. Cementitious Material: Use the following cementitious materials, of the same type, brand, and source throughout Project:

1. **Portland Cement:** ASTM C 150, Type I/II

ASTM C-150 Type I I/II cement is no longer available in the State of Hawaii. The cement supplier has switched to an ASTM C-595 Type 1L Cement.

2.08 CONCRETE MIXTURES FOR BUILDING ELEMENTS

4. Air Content: 6 percent, plus or minus 1.5 percent at point of delivery for /4-inch nominal maximum aggregate size.

The concrete mixtures are proportioned with 3% air content because the State of Hawaii is not in a Severe, Moderate and/or Mild Exposure zone with respect to freeze-thaw cycles.

2.10 CONCRETE MIXING

A. Ready-Mixed Concrete: Measure, batch, mix, and deliver concrete according to ASTM C 94 and ASTM C 1116 and furnish batch ticket information.

1. Mixing and Delivery Time: When air temperature is between 85 and 90 deg F, reduce mixing and delivery time from 1-1/2 hours to 75 minutes; when air temperature is above 90 deg F, reduce mixing and delivery time to 60 minutes.

The travel time from the batch plant to this project location will be about 45 minutes which will impact the time left for placement. The concrete mixtures can be designed to have an extended placement time of 120 minutes using a hydration-controlling admixture that is classified as an ASTM C494 Type B, Retarding, admixture. Therefore, "ABC Ready Mix" requests that this requirement be waived.

Use RFIs to call attention to potential issues in a specification.

https://www.bigrentz.com/blog/what-is-an-rfi

Outline

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Durability of Concrete

"The ability of a material to resist weathering action, chemical attack, abrasion, and other conditions of service."

ACI CT-23

Benefits of Durability

- Durability implies……
  - Increased service life
  - Minimal repair
  - Reduction in use of natural resources
  - Overall reduction in the carbon footprint of a structure
- Durability is key to "**Sustainability**" in the construction industry

Potential Concrete Durability Issues

- Corrosion of Steel Reinforcement
- Chemical Attack
  - Alkali-Silica Reaction (ASR)
  - Sulfates & Seawater
  - Aggressive (Industrial) Chemicals
- Freezing and Thawing
- Other (ex. abrasion resistance, cracking)

Credit: Portland Cement Association (PCA)

The High Cost of Corrosion

1992

2003

2019

The High Cost of Concrete Durability Issues

"At the Port Authority of NY & NJ, 99.99999% of repairs for transportation infrastructure are due to durability NOT compressive strength."

Cas Bognacki (rtd)
Chief of Materials

Addressing Potential Concrete Durability Issues

Durability-Based Design

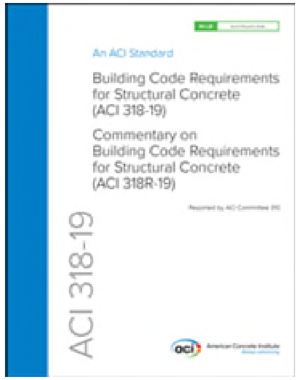
- Achieve design service life with minimal repairs, if any!
  - Corrosion protection of steel reinforcement
  - Resistance to physical & chemical attack
- **Requires performance-based specifications** & the development of appropriate durability test methods.

Credit: Portland Cement Association (PCA)

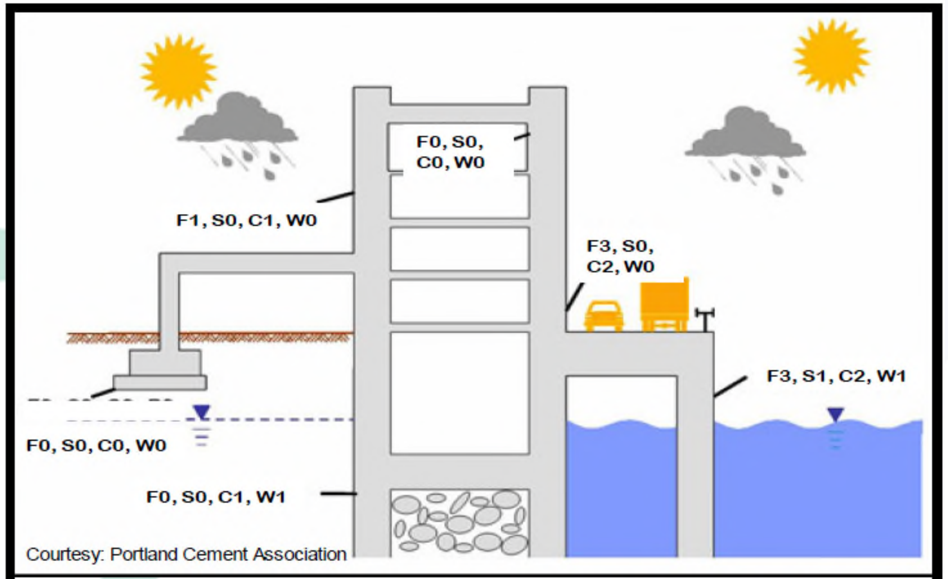
Performance-Based Specifications : Concrete Mixture

Push for performance-based specifications spurred the adoption of Exposure Classes in ACI CODE 318 & development of additional durability test methods.

ACI CODE 318 Durability Requirements for Concrete



- ACI 318-CODE-19 provides specific requirements for concrete for defined environmental exposure conditions.
  - min. f'_c; max. w/cm; air content
  - Types of cementitious materials (cm) & their limits
  - Limits on initial Cl^- content
- Chapter 19 of ACI 318-19, covers the following exposure categories, each with classes:
  - **F:** Concrete exposed to cycles of freezing and thawing
  - **S:** Concrete exposed to water soluble sulfate
  - **C:** Conditions requiring corrosion protection of reinforcement
  - **W:** Concrete members in contact with water



Durability Exposure Classes for Concrete Members

SOURCE: *PCA Design and Control of Concrete Mixtures*

ACI CODE 318 Durability Requirements for Concrete

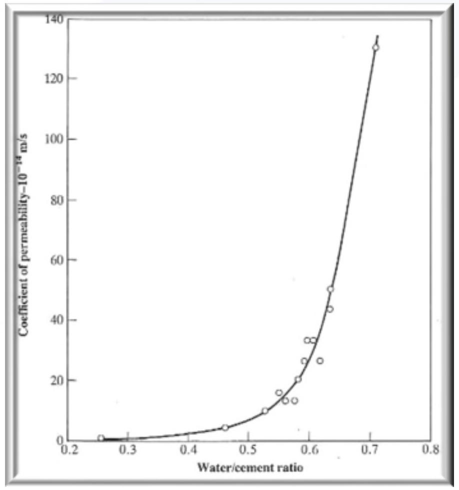
Table 19.3.1.1—Exposure categories and classes

Category	Class	Condition	
Freezing and thawing (F)	F0	Concrete not exposed to freezing-and-thawing cycles	
	F1	Concrete exposed to freezing-and-thawing cycles with limited exposure to water	
	F2	Concrete exposed to freezing-and-thawing cycles with frequent exposure to water	
	F3	Concrete exposed to freezing-and-thawing cycles with frequent exposure to water and exposure to deicing chemicals	
Sulfate (S)		Water-soluble sulfate (SO_4^{2-}) in soil, percent by mass[1]	Dissolved sulfate (SO_4^{2-}) in water, ppm[2]
	S0	$SO_4^{2-} < 0.10$	$SO_4^{2-} < 150$
	S1	$0.10 \le SO_4^{2-} < 0.20$	$150 \le SO_4^{2-} < 1500$ or seawater
	S2	$0.20 \le SO_4^{2-} \le 2.00$	$1500 \le SO_4^{2-} \le 10{,}000$
	S3	$SO_4^{2-} > 2.00$	$SO_4^{2-} > 10{,}000$
In contact with water (W)	W0	Concrete dry in service	
	W1	Concrete in contact with water where low permeability is not required	
	W2	Concrete in contact with water where low permeability is required	
Corrosion protection of reinforcement (C)	C0	Concrete dry or protected from moisture	
	C1	Concrete exposed to moisture but not to an external source of chlorides	
	C2	Concrete exposed to moisture and an external source of chlorides from deicing chemicals, salt, brackish water, seawater, or spray from these sources	

Table 19.3.2.1—Requirements for concrete by exposure class

Exposure class		Maximum *w/cm*[1,2]	Minimum f'_c, MPa	Additional requirements: Air content			Limits on cementitious materials
F0		N/A	17	N/A			N/A
F1		0.55	24	Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete			N/A
F2		0.45	31	Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete			N/A
F3		0.40[3]	35[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	17	No type restriction	No type restriction	No type restriction	No restriction
S1		0.50	28	II[5][6]	Types with (MS) designation	MS	No restriction
S2		0.45	31	V[6]	Types with (HS) designation	HS	Not permitted
S3	Option 1	0.45	31	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	35	V[8]	Types with (HS) designation	HS	Not permitted
W0		N/A	17	None			
W1		N/A	17	26.4.2.2(d)			
W2		0.50	28	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	17	1.00	0.06	None	
C1		N/A	17	0.30	0.06		
C2		0.40	35	0.15	0.06	Concrete cover[11]	

The most stringent provisions govern!



Ref: Neville and Brooks, 1987

ACI CODE 318 Durability Requirements for Concrete

26.4.1.5 *Admixtures*

26.4.1.5.1 Compliance requirements:

(a) Admixtures shall conform to (1) through (4):

R26.4.1.5 *Admixtures*

R26.4.1.5.1(a) ASTM C494 includes Type S—specific performance admixtures—that can be specified if perfor-

CODE

(1) Water reduction and setting time modification: ASTM C494.
(2) Producing flowing concrete: ASTM C1017.
(3) Air entrainment: ASTM C260.
(4) Inhibiting chloride-induced corrosion: ASTM C1582.

COMMENTARY

mance characteristics not listed in 26.4.1.5.1(a) are desired, such as viscosity-modifying admixtures. The basic requirement for a Type S admixture is that it will not have adverse effects on the properties of concrete when tested in accordance with ASTM C494. Meeting the requirements of Type S does not ensure that the admixture will perform its described function. The manufacturer of an admixture presented as conforming to Type S should also be required to provide data that the product will meet the performance claimed.

Note reference to corrosion-inhibiting admixtures (ASTM C1582)

FYI… International Building Code (IBC) References ACI CODE 318

CHAPTER19
CONCRETE ES

Italics are used for text within Sections 1903 through 1905 of this code to indicate provisions that differ from ACI 318.

User notes:

About this chapter: *Chapter 19 provides minimum accepted practices for the design and construction of buildings and structural components using concrete—both plain and reinforced. Chapter 19 relies primarily on the reference to American Concrete Institute (ACI) 318, Building Code Requirements for Structural Concrete. Structural concrete must be designed and constructed to comply with this code and all listed standards. There are also specific provisions addressing concrete slabs and shotcrete.*

Code development reminder: *Code change proposals to this chapter will be considered by the IBC—Structural Code Development Committee during the 2019 (Group B) Code Development Cycle.*

Increasingly, concrete structures are being designed for longer service lives!

Are the ACI CODE 318 Provisions enough?

ACI Durability Requirements for Concrete

Provisions in other documents may be <u>more restrictive</u> than the requirements in ACI CODE 318.

<u>ACI 362.1R</u>

6.1.2 *Durability recommendations* —Parking structures should meet the recommendations of the selected exposure zone in Tables 6.3.1.6a, 6.3.1.6b, 6.3.2.2a, and 6.3.2.2b. <u>Some recommendations in this guide are more restrictive than those of ACI 318-11</u>. After selecting the appropriate exposure zone and construction type, the designer should reference the four tables in Section 6.3 and determine the minimum design criteria.

Performance-Based Specifications: Concrete Mixture

Concrete Mixture:

- Strength (compressive / flexural)
- Modulus of Elasticity (MOE)
- Permeability or Transport Properties
  - RCPT (ASTM C 1202)
  - Chloride Diffusion Coefficient
  - Resistivity
- Volume Change
  - Cracking
- Chemical Reaction
  - Alkali-Silica Reaction (ASR)

Property	Test Method
Compressive Strength	ASTM C 39
Flexural Strength	ASTM C 78
Modulus of Elasticity	ASTM C 469
Permeability:	
• RCPT	ASTM C 1202
• Chloride Diffusion Coefficient	ASTM C 1556
• Surface Resistivity	AASHTO T 358
• Bulk Electrical Resistivity	ASTM C 1876
Volume Change:	
• Drying Shrinkage	ASTM C 157
• Time to Cracking	ASTM C 1581
Chemical Reaction:	
• Alkali-Silica Reaction (ASR)	ASTM C 1260, C 1567, C 1293

Plan Ahead!

- Time
- May require specialized testing and expertise
- Cost

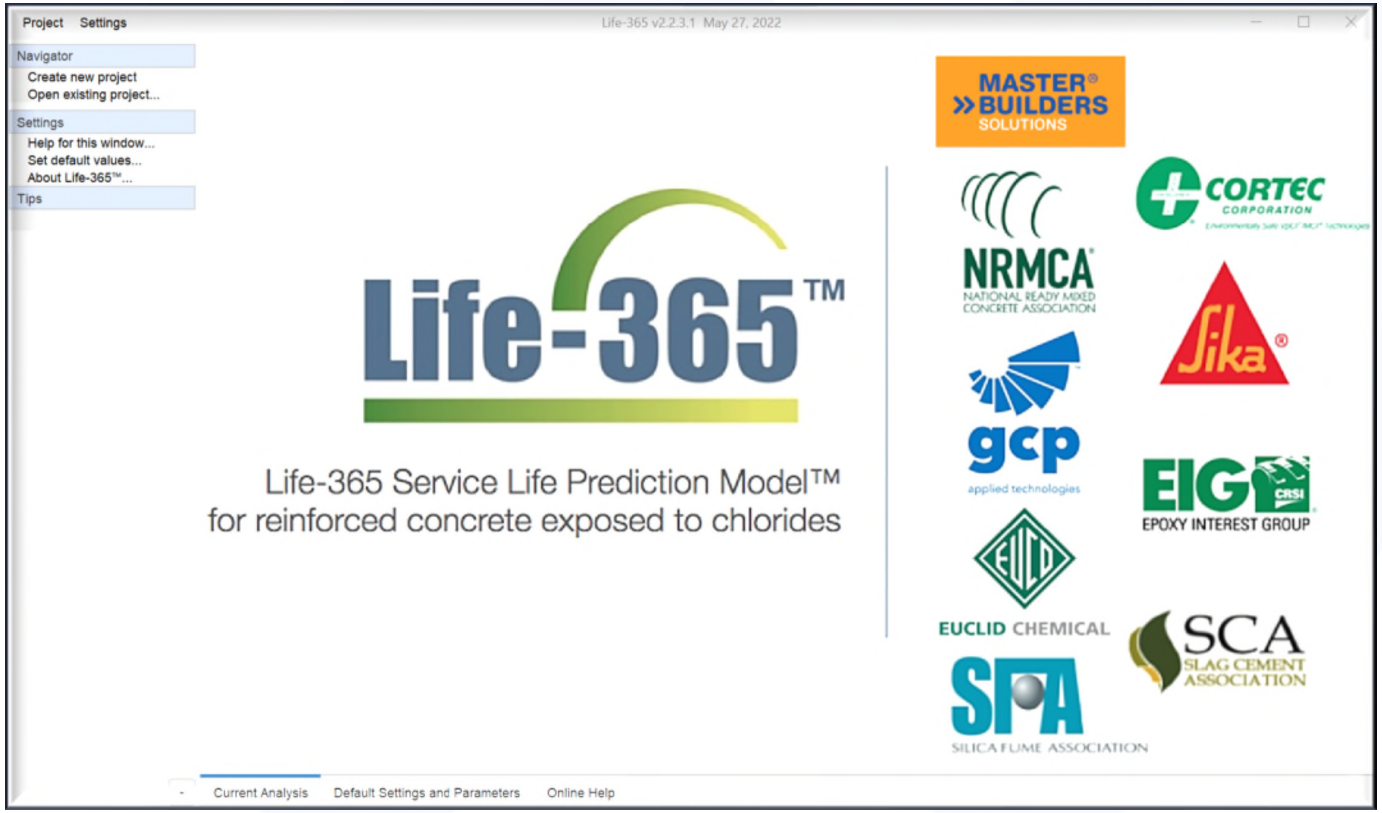
Confederation Bridge; Prince Edward Island, Canada

- 8-mile (12.9-km) Long Bridge
  - precast, post-tensioned segmental box girder structure
  - Tight construction schedule – 33 months!
  - 35-year Build-Operate-Transfer contract
- Design Criteria
  - **Extended Service Life of 100 years ← D_{eff} specified!** (*the first of its magnitude in Canada*)
- Durability Issues included:
  - Abrasion and impact of ice on the piers
  - Corrosion of reinforcement in a marine environment
  - Alkali-aggregate reactivity and sulfate attack
  - Freezing & thawing resistance / salt scaling

Corrosion Service Life Prediction Models

North America:

- Life 365^{TM} (free)
- Stadium®



Links

http://www.life-365.org

http://www.simcotechnologies.com

Caltrans Requirements for Concrete in Corrosive Environment

Corrosion Guidelines
MAY 2021
Version 3.2

NOTICE

The contents of this document reflect the views of Materials Engineering and Testing Services which is responsible for the facts and the accuracy of the guidelines presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. **These guidelines do not constitute a standard, specification, or regulation.**

Neither the State of California nor the United States Government endorses products or manufacturers. Trade or manufacturers' names appear herein only because they are considered essential to the object of this document.

Comments on these Corrosion Guidelines should be directed to:

Steve Seifert, Senior
Corrosion Branch

via e-mail

Steven.Seifert@dot.ca.gov

or

via US Mail

California Department of Transportation
Materials Engineering and Testing Services
Corrosion Branch
5900 Folsom Blvd., Sacramento, CA 95819

Corrosion Guidelines
MAY 2021
Version 3.2

6. CORROSIVE ENVIRONMENT

The Department has adopted the American Association of State Highway Transportation Officials (AASHTO) ***Load and Resistance Factor Design (LRFD) Bridge Specification*** requirement for a 75-year structure design life. However, culverts and drainage facilities typically require a 50-year maintenance free design life. ***Table 5.10.1-1 Minimum Concrete Cover to Reinforcement (in.) for 75-year Design Life*** of ***Section 5.10.1*** (see References) ***Section 5 Concrete Structures*** of ***California Amendments (to the AASHTO LRFD Bridge Design Specifications)*** provides the four exposure conditions found in California.

A. Non-Corrosive – soils and waters that are not corrosive to metals or concrete and do not meet the requirements in Section 6.1 below for a corrosive site.

B. Non-Marine – Soils and waters that meet the requirements stated below in Section 6.1 for a corrosive site and not within 1000 feet of a marine surface body of water. This exposure describes the soil above and extending down to 3 feet below the current lowest ground water elevation or 3 feet below the lowest recorded/measured ground water elevation. This also applies to corrosive ground water.

C. Marine
   a. Atmosphere – Structural elements exposed to the atmosphere over land within 1000 ft of ocean or marine water and the atmosphere above the splash zone. Marine water, from corrosion considerations, is any body of water having a chloride content greater than or equal to 500 ppm.
   b. Water Permanently Below MLLW Level – Structural elements permanently immersed 3 ft below the Mean Lower Low Water (MLLW) elevation.
   c. Splash Zone – Structural elements exposed to marine water extending from 3 ft below the MLLW to 20 ft above the Mean Higher High Water (MHHW) elevation and 20 ft from the edge of water at the MHHW.

D. Freeze/Thaw - Structural elements exposed directly to freezing/thawing cycles and or de-icing salts, snow run-off or snow blower spray.

75-year design life for bridges

Caltrans Requirements for Concrete in Corrosive Environment

Corrosion protection of reinforced concrete is required in accordance with ***Section 5 Concrete Structures*** of ***California Amendments (to the AASHTO LRFD Bridge Design Specifications)*** most current edition (see References). ***Table 5.10.1-1 Minimum Concrete Cover to Reinforcement (in.) for 75-year Design Life*** specifies the use of increased clear concrete cover over the reinforcing steel, corrosion resistant concrete mix designs, reduced water to binder ratio as well as reinforcement coatings (***Authorized Material Lists***) and stainless steel for corrosion protection of reinforced concrete exposed to chloride environments. This document also provides mitigation measures to protect against corrosion due to acids or sulfates.

Section 90-1.02H Concrete in Corrosive Environments of the ***Standard Specifications*** provides specification language for corrosion resistant concrete mix designs that address corrosive conditions specified in ***Section 5 Concrete Structures California Amendments*** above.

Concrete mixes used by the Department to mitigate chlorides are based on the diffusion rate of chlorides using Fick's Second Law of Diffusion. Dense concrete mixes that are less permeable slow the diffusion of chlorides through concrete. Therefore, the time for chlorides in the soil or water to reach the reinforcing steel is increased. It is desirable to slow the rate of chloride diffusion in reinforced concrete because high chloride contents at the level of the reinforcing steel will cause the reinforcing steel to corrode.

12-1

Caltrans

Corrosion Guidelines
MAY 2021
Version 3.2

The use of supplementary cementitious materials (such as fly ash, granulated blast-furnace slag (GGBS), silica fume, metakaolin, etc.), reduced water content and increased cementitious material content result in high-density, durable concrete. Additional thickness of clear cover over the reinforcing steel also increases the time it takes for chlorides to reach the level of the reinforcement. ***Bridge Memo to Designers 3-1*** and ***10-5*** (see References) provides additional guidance regarding protection against corrosion for reinforced concrete due to chlorides, sulfates, and acids.

https://dot.ca.gov/-/media/dot-media/programs/engineering/documents/mets/corrosion-guidelines-a11y.pdf

Caltrans Requirements for Concrete in Corrosive Environment

90-1.02H Concrete in Corrosive Environments

Section 90-1.02H applies to concrete specified in the special provisions to be in a corrosive environment.

The cementitious material to be used in the concrete must be a combination of Type II or V portland cement and SCM.

The concrete must contain at least 675 pounds of cementitious material per cubic yard.

The reduction of cementitious material content as specified in section 90-1.02E(2) is not allowed.

The specifications for SCM content in section 90-1.02B(3) do not apply.

1202

SECTION 90 **CONCRETE**

The cementitious material must be composed of one of the following, by weight:

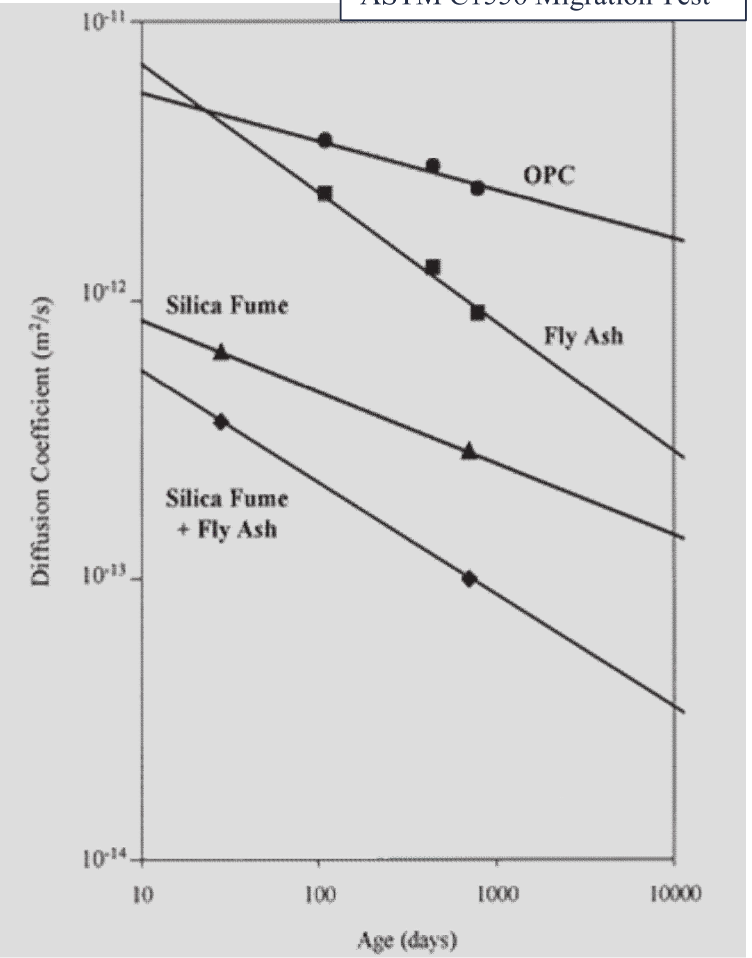
1. 25 percent natural pozzolan or fly ash with a CaO content of up to 10 percent and 75 percent portland cement
2. 20 percent natural pozzolan or fly ash with a CaO content of up to 10 percent, 5 percent silica fume, and 75 percent portland cement
3. 12 percent silica fume, metakaolin, or UFFA, and 88 percent portland cement
4. 50 percent GGBFS and 50 percent portland cement

Performance or Prescriptive?

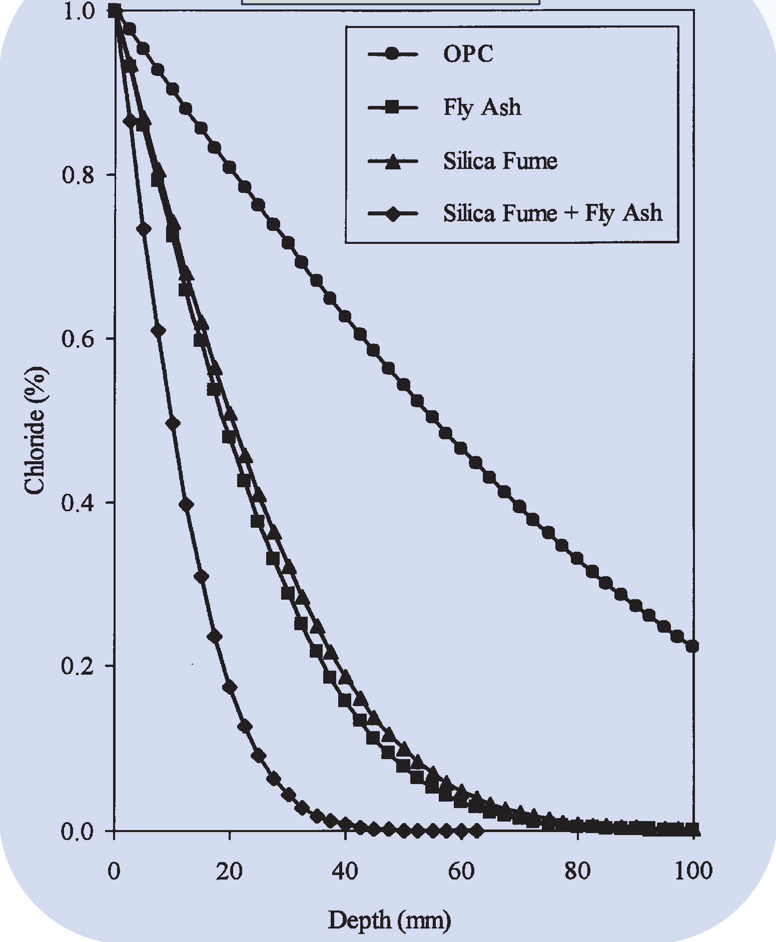
https://dot.ca.gov/-/media/dot-media/programs/engineering/documents/mets/corrosion-guidelines-a11y.pdf

Design for Durability: Benefits of SCMs on Chloride Ingress

ASTM C1556 Migration Test



Numerical Modeling



Source: Thomas et al. (1999)

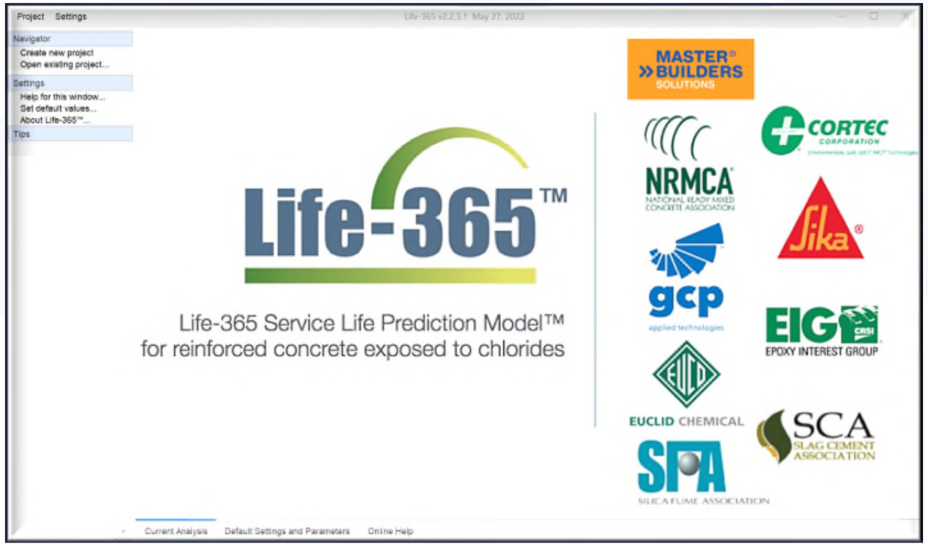
Corrosion Service Life Prediction Using Caltrans Options

Table 5.10.1-1—Minimum Concrete Cover to Reinforcement (in.) for 75-year Design Life

Structural Elements	Exposure condition									
	Non-Corrosive	Non-Marine			Marine					Freeze/ Thaw
	Atmosphere /soil/water	Corrosive soil above and extending down to 3 feet below the current lowest ground water elevation or 3 feet below the lowest recorded/measured ground water elevation Chloride Concentration (ppm)			Atmosphere **(a)**	Water Permanently below MLLW level **(a), (b)**	Splash zone Chloride Concentration (ppm)			De-icing salt, snow run-off, or snow blower spray **(a), (c), (e)**
		500-5,000 **(a)**	5,001-10,000 **(a)**	Greater than 10,000 **(a)**			500-5,000 **(a), (b)**	5,001-10,000 **(a), (b)**	Greater than 10,000 **(a), (b)**	
Footings & pile caps	3	3	4	5	3	2	2	3	3.5	2.5
Walls, columns & cast-in-place piles	2	3	4	5	3	2	2	3	3.5	2.5
Precast piles and Pile Extensions	2	2[d]	2[b] [d]	2.5[b] [d]	2[d]	2	2	2[d]	3[d]	2[d]
Top surface of deck slabs and top surface of slab bridges	2				2.5		2.5	2.5	2.5[d]	2.5
Bottom surface of deck slabs[g]	1.5				1.5		2	2.5	2.5[d]	2.5
Bottom surface of box girder bottom slabs and bottom surface of slab bridges	1.5				1.5		2	2.5	2.5[d]	1.5
Exposed faces of box girder webs and all other exposed girders. Bent caps, diaphragms and hinged joints [f]	1.5				3.0		2	2.5	2.5[d]	3.0
Curbs & railings	1				1[b]		1	1	1[d]	1

Continued on next page

Materials	Section 90-1.02H Option			
	1	2	3	4
Portland Cement	75	75	88	50
Class F Fly Ash	25	20	-	-
Silica Fume	-	5	12	-
Slag Cement	-	-	-	50



Life-365 Corrosion Service Life Prediction Using Caltrans Options

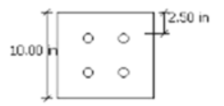
Life-365 v2.2 - Concrete Mixes and Service Lives

Project: Caltrans Section 90-1.-2H Options

Description: Caltrans Options for Concrete in Corrosive Environments

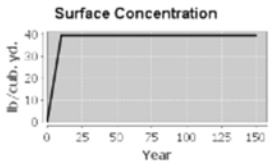
Analyst: Analyst

Date: 10/03/2021



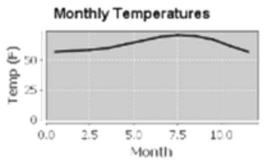
slabs and walls (1-D)

Outer dim: 10in; clear cover: 2.5in



Max surface: 39.490 lb/cub. yd.

Years to buildup: 10



Loc: California: LOS ANGELES

Type: Marine spray zone

Concrete Mixes

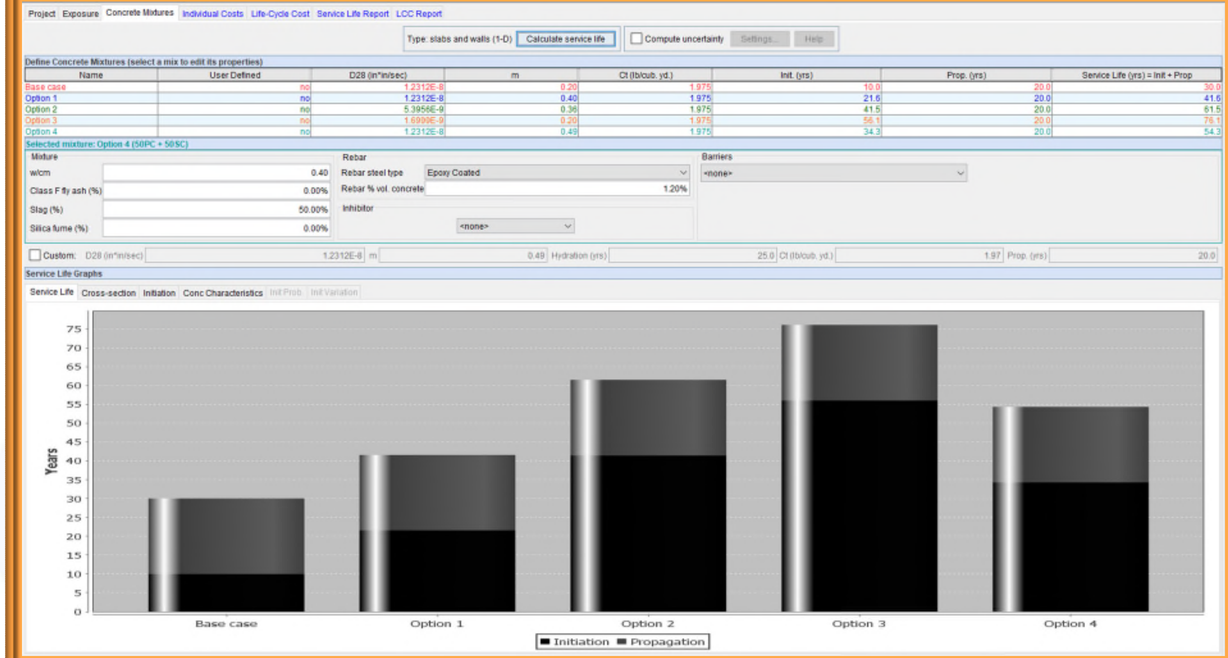
Alt name	User?	w/cm	SCMs	Inhib.	Barrier	Reinf.
Base case		0.4				Epoxy Coated
Option 1		0.4	Class F Fly Ash (25%);			Epoxy Coated
Option 2		0.4	Class F Fly Ash (20%); Silica Fume (5%);			Epoxy Coated
Option 3		0.4	Silica Fume (12%);			Epoxy Coated
Option 4		0.4	Slag (50%);			Epoxy Coated

"n/a" indicates that, since the user is specifying the diffusion properties of this mix, this value is not specified.

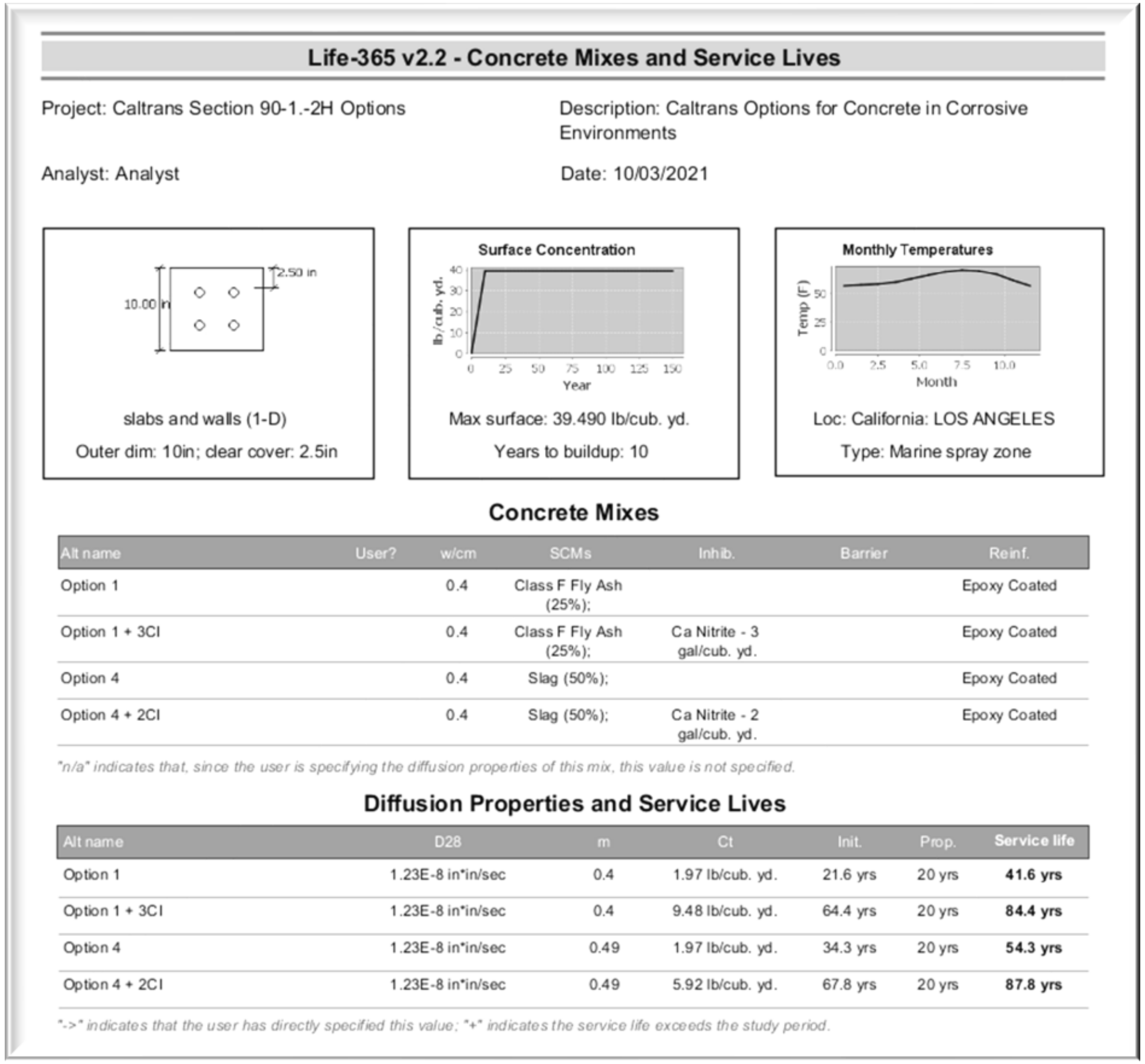
Diffusion Properties and Service Lives

Alt name	D28	m	Ct	Init.	Prop.	Service life
Base case	1.23E-8 in*in/sec	0.2	1.97 lb/cub. yd.	10 yrs	20 yrs	**30 yrs**
Option 1	1.23E-8 in*in/sec	0.4	1.97 lb/cub. yd.	21.6 yrs	20 yrs	**41.6 yrs**
Option 2	5.40E-9 in*in/sec	0.36	1.97 lb/cub. yd.	41.5 yrs	20 yrs	**61.5 yrs**
Option 3	1.70E-9 in*in/sec	0.2	1.97 lb/cub. yd.	56.1 yrs	20 yrs	**76.1 yrs**
Option 4	1.23E-8 in*in/sec	0.49	1.97 lb/cub. yd.	34.3 yrs	20 yrs	**54.3 yrs**

"->" indicates that the user has directly specified this value; "+" indicates the service life exceeds the study period.



What About Other Options? Ex. Corrosion Inhibitors



Life-365 v2.2 - Concrete Mixes and Service Lives

Project: Caltrans Section 90-1.-2H Options

Description: Caltrans Options for Concrete in Corrosive Environments

Analyst: Analyst

Date: 10/03/2021

Concrete Mixes

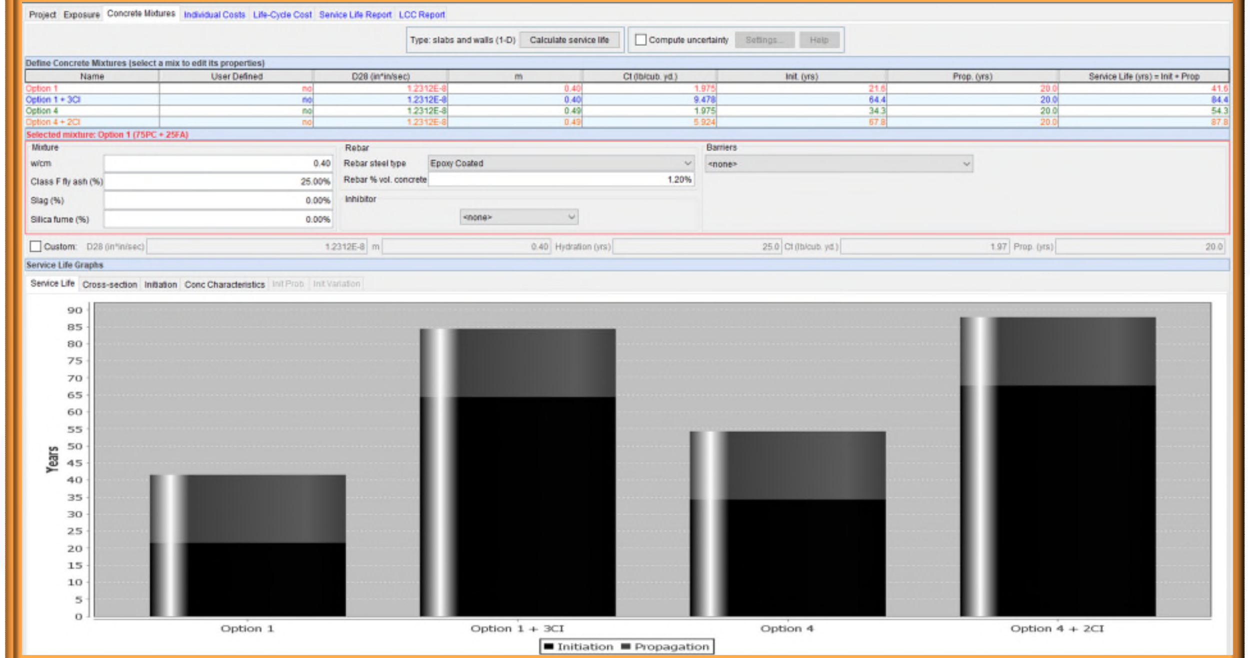
Alt name	User?	w/cm	SCMs	Inhib.	Barrier	Reinf.
Option 1		0.4	Class F Fly Ash (25%);			Epoxy Coated
Option 1 + 3CI		0.4	Class F Fly Ash (25%);	Ca Nitrite - 3 gal/cub. yd.		Epoxy Coated
Option 4		0.4	Slag (50%);			Epoxy Coated
Option 4 + 2CI		0.4	Slag (50%);	Ca Nitrite - 2 gal/cub. yd.		Epoxy Coated

"n/a" indicates that, since the user is specifying the diffusion properties of this mix, this value is not specified.

Diffusion Properties and Service Lives

Alt name	D28	m	Ct	Init.	Prop.	Service life
Option 1	1.23E-8 in*in/sec	0.4	1.97 lb/cub. yd.	21.6 yrs	20 yrs	**41.6 yrs**
Option 1 + 3CI	1.23E-8 in*in/sec	0.4	9.48 lb/cub. yd.	64.4 yrs	20 yrs	**84.4 yrs**
Option 4	1.23E-8 in*in/sec	0.49	1.97 lb/cub. yd.	34.3 yrs	20 yrs	**54.3 yrs**
Option 4 + 2CI	1.23E-8 in*in/sec	0.49	5.92 lb/cub. yd.	67.8 yrs	20 yrs	**87.8 yrs**

"->" indicates that the user has directly specified this value; "+" indicates the service life exceeds the study period.



What About Other Options? Ex. Increased Concrete Cover

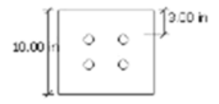
Life-365 v2.2 - Concrete Mixes and Service Lives

Project: Caltrans Section 90-1.-2H Options

Description: Caltrans Options for Concrete in Corrosive Environments

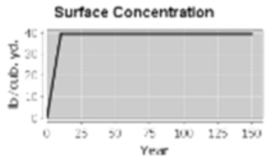
Analyst: Analyst

Date: 10/03/2021



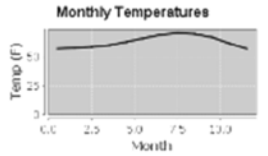
slabs and walls (1-D)

Outer dim: 10in; clear cover: 3in



Max surface: 39.490 lb/cub. yd.

Years to buildup: 10



Loc: California: LOS ANGELES

Type: Marine spray zone

Concrete Mixes

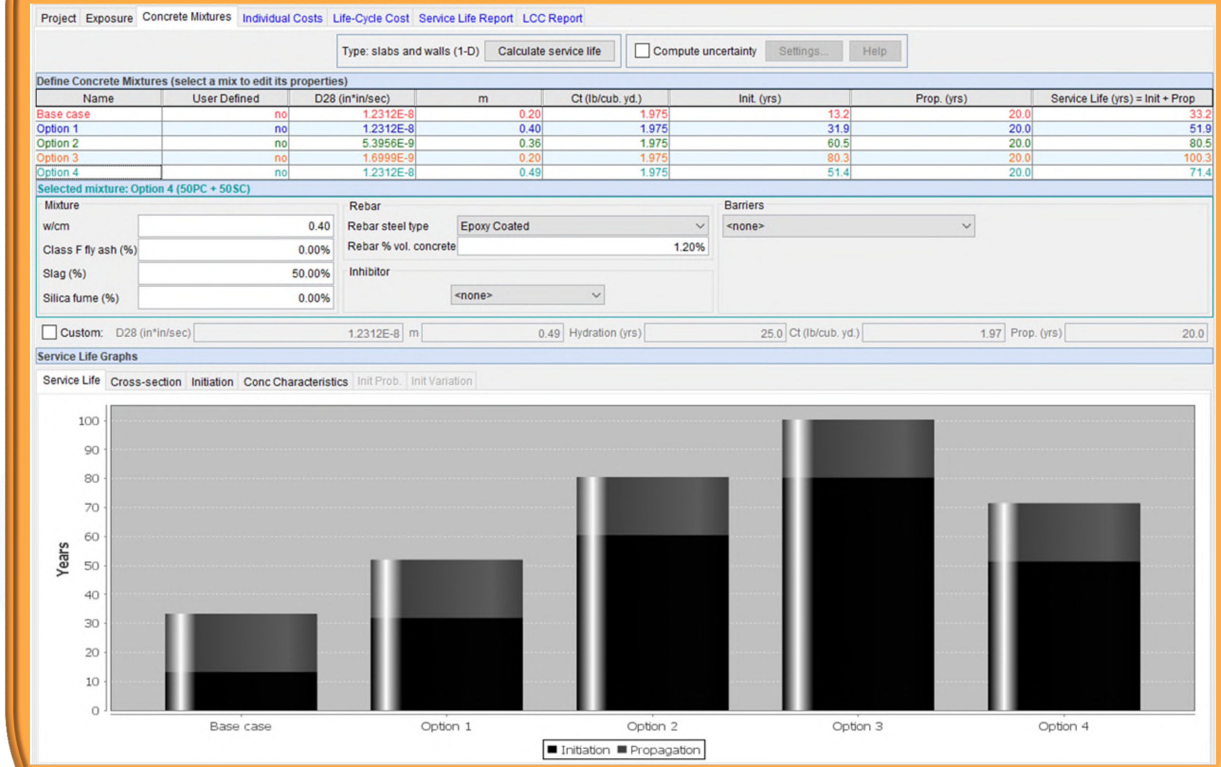
Alt name	User?	w/cm	SCMs	Inhib.	Barrier	Reinf.
Base case		0.4				Epoxy Coated
Option 1		0.4	Class F Fly Ash (25%);			Epoxy Coated
Option 2		0.4	Class F Fly Ash (20%); Silica Fume (5%);			Epoxy Coated
Option 3		0.4	Silica Fume (12%);			Epoxy Coated
Option 4		0.4	Slag (50%);			Epoxy Coated

"n/a" indicates that, since the user is specifying the diffusion properties of this mix, this value is not specified.

Diffusion Properties and Service Lives

Alt name	D28	m	Ct	Init.	Prop.	Service life
Base case	1.23E-8 in*in/sec	0.2	1.97 lb/cub. yd.	13.2 yrs	20 yrs	**33.2 yrs**
Option 1	1.23E-8 in*in/sec	0.4	1.97 lb/cub. yd.	31.9 yrs	20 yrs	**51.9 yrs**
Option 2	5.40E-9 in*in/sec	0.36	1.97 lb/cub. yd.	60.5 yrs	20 yrs	**80.5 yrs**
Option 3	1.70E-9 in*in/sec	0.2	1.97 lb/cub. yd.	80.3 yrs	20 yrs	**100.3 yrs**
Option 4	1.23E-8 in*in/sec	0.49	1.97 lb/cub. yd.	51.4 yrs	20 yrs	**71.4 yrs**

"->" indicates that the user has directly specified this value; "+" indicates the service life exceeds the study period.



What About Other Options? Contractor Option??

Under Consideration

Outline

I. Review of Types of Construction Specifications

2. Durability & Sustainability of Concrete

3. LECC – Challenges & Opportunities

4. Summary / Questions

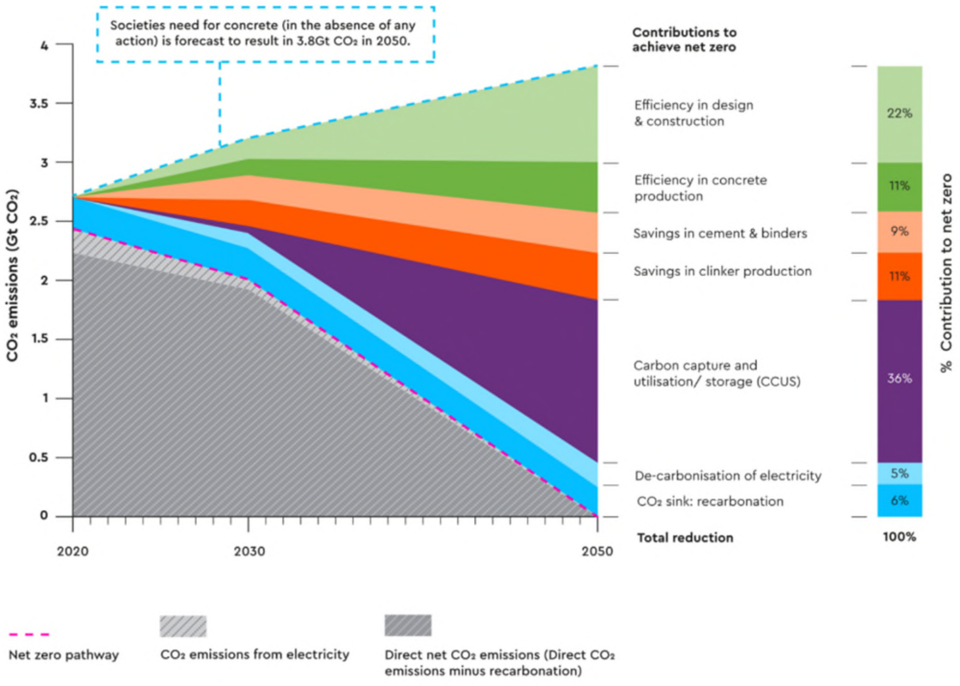
The Concrete Industry is Undergoing a Disruptive Transformation!

How Are you Coping?

Trends that are Transforming the Concrete Industry

Sustainability

Increased awareness that the embodied carbon of concrete must be reduced!



Quantifying Sustainability… EPDs

Nutrition Facts

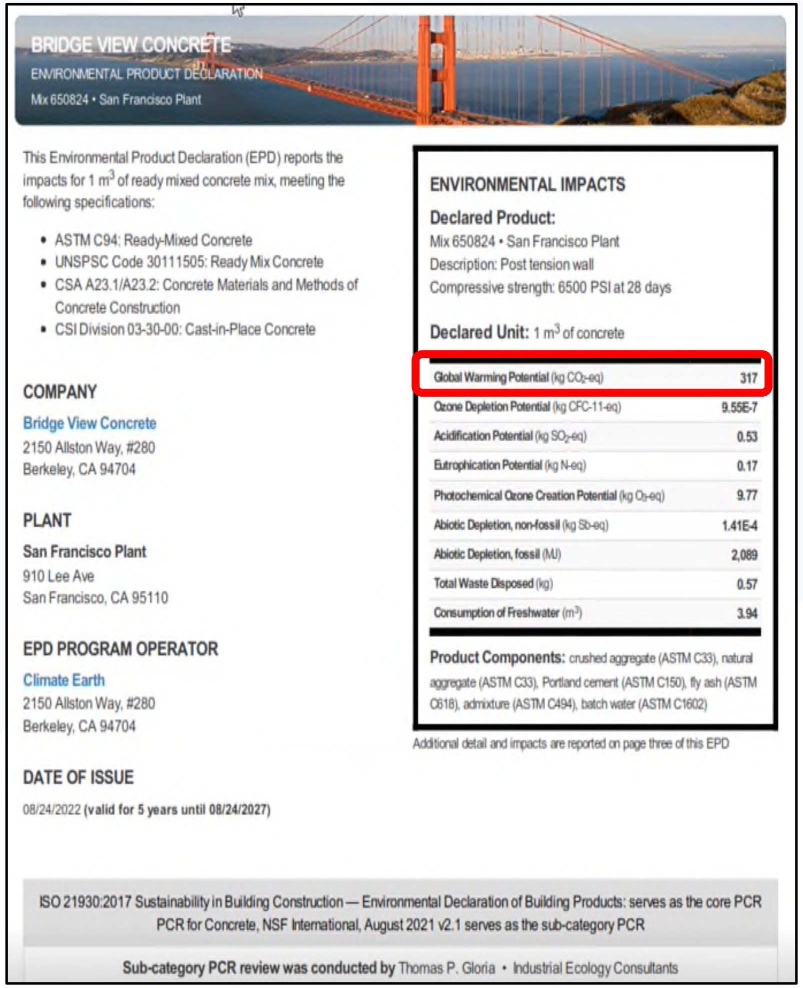
Serving Size 2/3 cup (55g)
Servings Per Container About 8

Amount Per Serving	
Calories 230	Calories from Fat 40
	% Daily Value*
Total Fat 8g	12%
Saturated Fat 1g	5%
Trans Fat 0g	
Cholesterol 0mg	0%
Sodium 160mg	7%
Total Carbohydrate 37g	12%
Dietary Fiber 4g	16%
Sugars 1g	
Protein 3g	

"Nutritional" Label based on Environmental Factors!

Consumption of Energy	Emissions	Toxicity Potential	Risk Potential	Consumption of Raw Materials	Land Use
• Cumulative energy utilized in the cradle-to-gate analysis • Fossil and renewable resources are included	• Described by categories - Air - Water - Solids	• Potential effect on human health toxicity	• Potential for physical hazard (accident and occupational disease) • Based on published statistical data	• Materials are weighted according to reserves and global consumption	• Degree of land development needed to fulfill the production of concrete

Global Warming Potential
Ozone Depletion Potential
Photochemical Ozone Creation Potential
Acidification Potential


BRIDGE VIEW CONCRETE
ENVIRONMENTAL PRODUCT DECLARATION
Mix 650824 • San Francisco 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
Bridge View Concrete
2150 Allston Way, #280
Berkeley, CA 94704

PLANT
San Francisco Plant
910 Lee Ave
San Francisco, CA 95110

EPD PROGRAM OPERATOR
Climate Earth
2150 Allston Way, #280
Berkeley, CA 94704

DATE OF ISSUE
08/24/2022 **(valid for 5 years until 08/24/2027)**

ENVIRONMENTAL IMPACTS

Declared Product:
Mix 650824 • San Francisco Plant
Description: Post tension wall
Compressive strength: 6500 PSI at 28 days

Declared Unit: 1 m^3 of concrete

Global Warming Potential (kg CO_2-eq)	317
Ozone Depletion Potential (kg CFC-11-eq)	9.55E-7
Acidification Potential (kg SO_2-eq)	0.53
Eutrophication Potential (kg N-eq)	0.17
Photochemical Ozone Creation Potential (kg O_3-eq)	9.77
Abiotic Depletion, non-fossil (kg Sb-eq)	1.41E-4
Abiotic Depletion, fossil (MJ)	2,089
Total Waste Disposed (kg)	0.57
Consumption of Freshwater (m^3)	3.94

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

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

Source: ClimateEarth.com

Quantifying Sustainability… EPD Baseline Values

2023 Carbon Leadership Forum

North American Material Baselines

BASELINE REPORT v2 | AUGUST 2023

CLF Carbon Leadership Forum

2021 BASELINE FIGURES

Version 2.0, July 2021

Category	Subtype	2021 CLF BASELINES v2 kg CO2e per declared unit: Achievable (Low)	Typical (Median)	Baseline (High)	Declared unit	Method	Data Source & Notes
CONCRETE							
Ready Mixed Concrete	0-2500 psi (0-17.2 Mpa)	190	266	**340**	m3	1	Typical = NRMCA USA benchmark value per strength class (NRMCA, 2020, Table E1); Low = IW-EPD Ready Mixed Concrete (NRMCA, 2019) minimum value per strength class; High = IW-EPD Ready Mixed Concrete (NRMCA, 2019) maximum value per strength class + uncertainty factor to account for cement variation (Building Transparency analysis, citation forthcoming). Note that the NRMCA Industry Average EPD (NRMCA, 2019) provides data for strength ranges (e.g., 3001 - 4000 psi), while the NRMCA Benchmark Report (NRMCA, 2020) provides data for specific strength values (e.g., 4000
	2501-3000 psi (17.2-20.7 MPa)	210	291	**380**	m3	1	
	3001-4000 psi (20.7-27.6 MPa)	260	343	**470**	m3	1	
	4001-5000 psi (27.6-34.5 MPa)	320	406	**580**	m3	1	
	5001-6000 psi (34.5-41.4 MPa)	330	429	**610**	m3	1	
	6001-8000 psi (41.3-55.1 MPa)	380	498	**710**	m3	1	
	>8001 psi (>55.1 MPa)	411	535	**710**	m3	1	
Slurry	Flowable Fill	90	170	**230**	m3	2	
	Structural Grout	270	458	**620**	m3	2	
Shotcrete		Match ready mixed concrete values per strength			m3	4	
MASONRY							
Concrete Masonry Unit		TBD	370	**545**	m3	2	

2023 BASELINES VALUES

General Notes

- Baseline GWP values represent life cycle stages A1-A3 unless stated otherwise.
- Baseline GWP values are representative of North American manufacturing, acknowledging global trade for upstream supply chain materials.
- Generally, the Baseline GWP values use the same number of significant digits used in the original data source. Where CLF performs a calculation to establish a baseline GWP value (e.g., averaging multiple values or converting between fabricated and unfabricated steel product GWP), these values are rounded to two or three significant digits.
- Category appendices include full citations for the data sources listed here.

Table 1: USA Ready-Mixed Concrete Regional and National Baselines

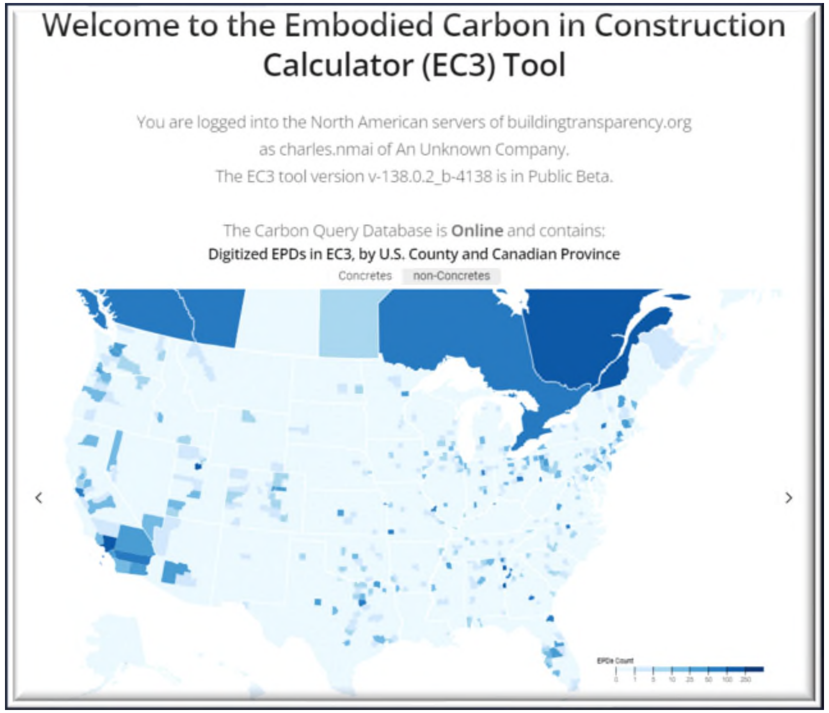
	2500 psi (17.2 MPa)	3000 psi (20.7 MPa)	4000 psi (27.6 MPa)	5000 psi (34.5 MPa)	6000 psi (41.4 MPa)	8000 psi (55.1 MPa)	LW 3000 psi (20.7 MPa)	LW 4000 psi (27.6 MPa)	LW 5000 psi (34.5 MPa)
Pacific Southwest	257	279	323	378	401	456	500	546	594
Pacific Northwest	235	261	316	386	408	487	518	575	632
Rocky Mountains	232	255	301	358	379	440	484	532	580
South Central	226	245	286	336	356	409	468	510	555
North Central	241	264	312	372	394	460	487	537	591
Southeastern	247	268	309	360	382	435	478	521	562
Great Lakes	232	255	303	363	383	452	499	551	603
Eastern	240	264	314	378	399	472	517	573	628
National	240	262	308	365	385	446	492	540	588

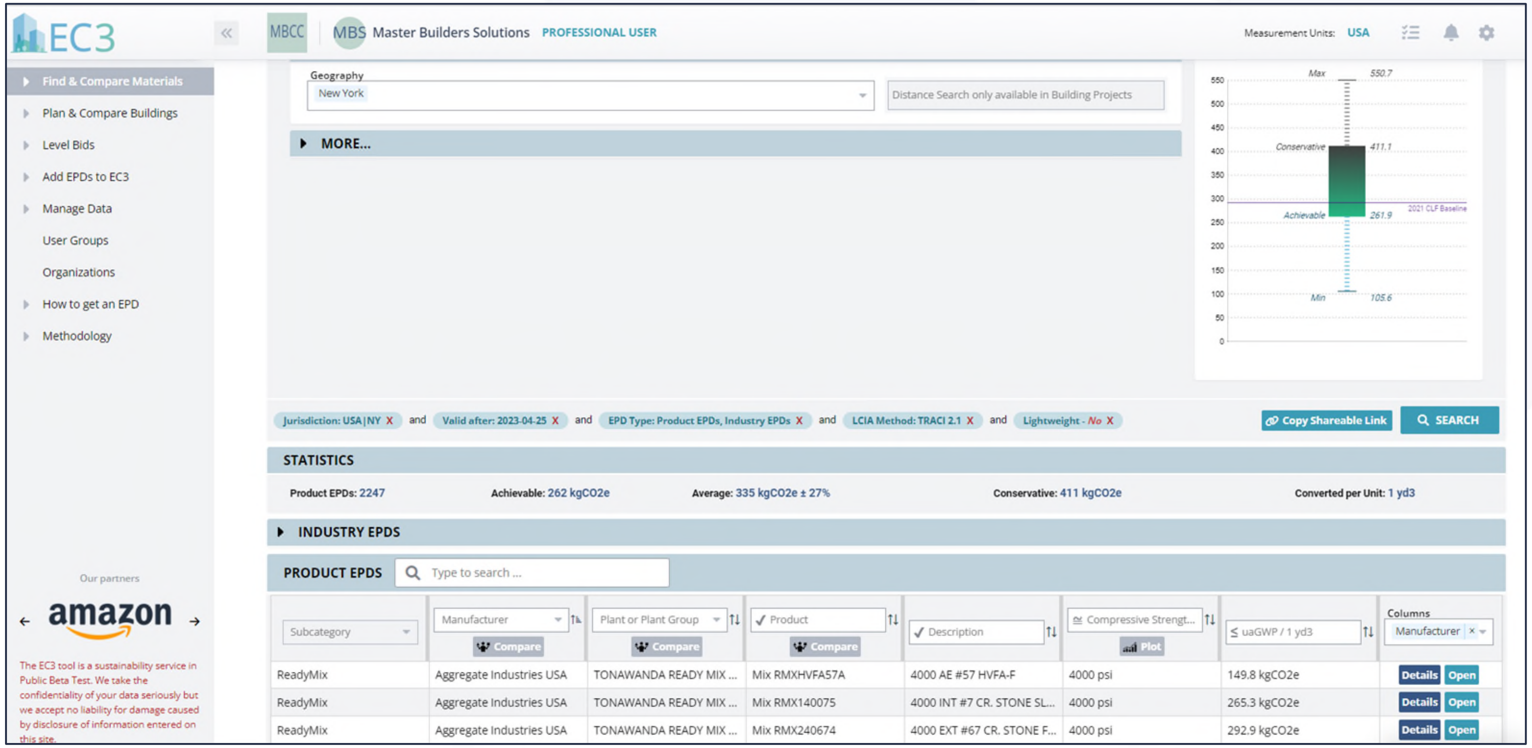
Notes: All values are Baseline GWP (kg CO_2e / m³).

Data Source: NRMCA. (2022). *National and regional LCA benchmark (industry average) report - v3.2*

It's work in Progress!!!

EC3 – Where Design Professionals Go for EPDs!





https://buildingtransparency.org/ec3/material-search

EC3 – Where Design Professionals Go for EPDs!

https://buildingtransparency.org/ec3/material-search

Low-Carbon Concrete Policy Initiatives… Marin County, CA (2020)

Select Language ▾ Accessibility A A A Text Resize Skip To Main Content

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You are here: Home > Departments > Community Development Agency > Sustainability > Low Carbon Concrete Requirements

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Community Development Agency
- Building and Safety
- Environmental Health Services

Low-Carbon Concrete Requirements

Community Development Agency

All building project applicants, contractors, and concrete suppliers are required to comply with low carbon concrete code in keeping with Title 19 Marin County Building Code, Chapter 19.07 - Carbon Concrete Requirements. Compliance includes two pathways to reduce greenhouse gas emissions by reducing cement levels or replacing lower carbon emitting cementitious materials in concrete designs.

If you have any questions about Marin County's Low Carbon Concrete policy, contact greenbuilding@marincounty.org or call us at (415) 473-2797.

19.07.050 – Compliance

Compliance with the requirements of this chapter shall be demonstrated through any of the compliance options in Sections 19.07.050.2 through 19.07.050.5.

Table 19.07.050 Cement and Embodied Carbon Limit Pathways

	Cement limits for use with any compliance method 19.07.050.2 through 19.07.050.5	**Embodied Carbon limits** for use with any compliance method 19.07.050.2 through 19.07.050.5
Minimum specified compressive strength f'_c, psi (1)	Maximum ordinary Portland cement content, lbs/yd³ (2)	Maximum embodied carbon kg CO_2e/m^3, per EPD
up to 2500	362	260
3000	410	289
4000	456	313
5000	503	338
6000	531	356
7000	594	394
7001 and higher	657	433
up to 3000 light weight	512	578
4000 light weight	571	626
5000 light weight	629	675

Notes
(1) For concrete strengths between the stated values, use linear interpolation to determine cement and/or embodied carbon limits.
(2) Portland cement of any type per ASTM C150.

https://www.stopwaste.org/sites/default/files/Marin%20County%20low-carbon-concrete-code.pdf

Big Drivers of the Movement: American Concrete Institute (ACI)

ACI CODE-323 was open for public comment March 31, 2024, until May 15, 2024.

https://twitter.com/ConcreteACI/status/1735687412892729454

This draft is not final and is subject to revision. Do not circulate or publish.

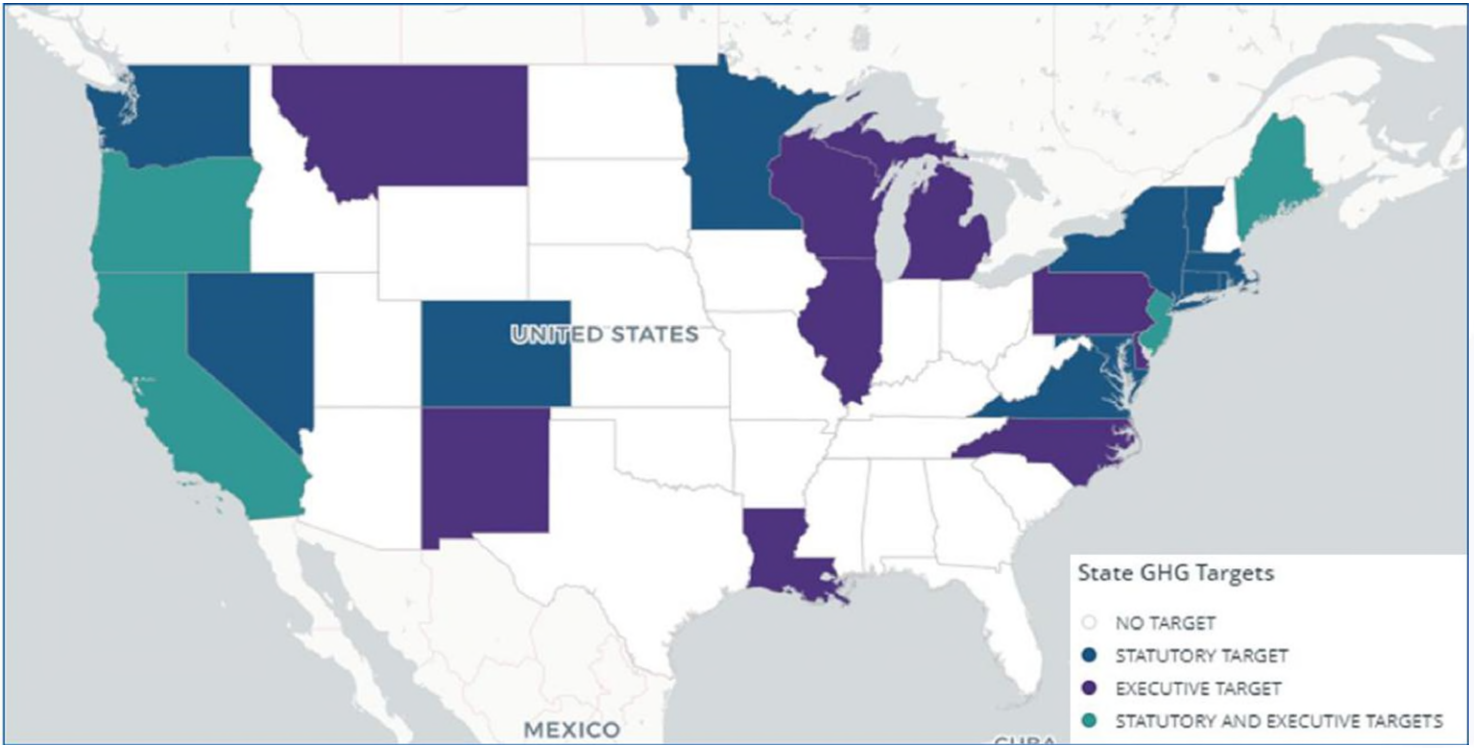
PREFACE

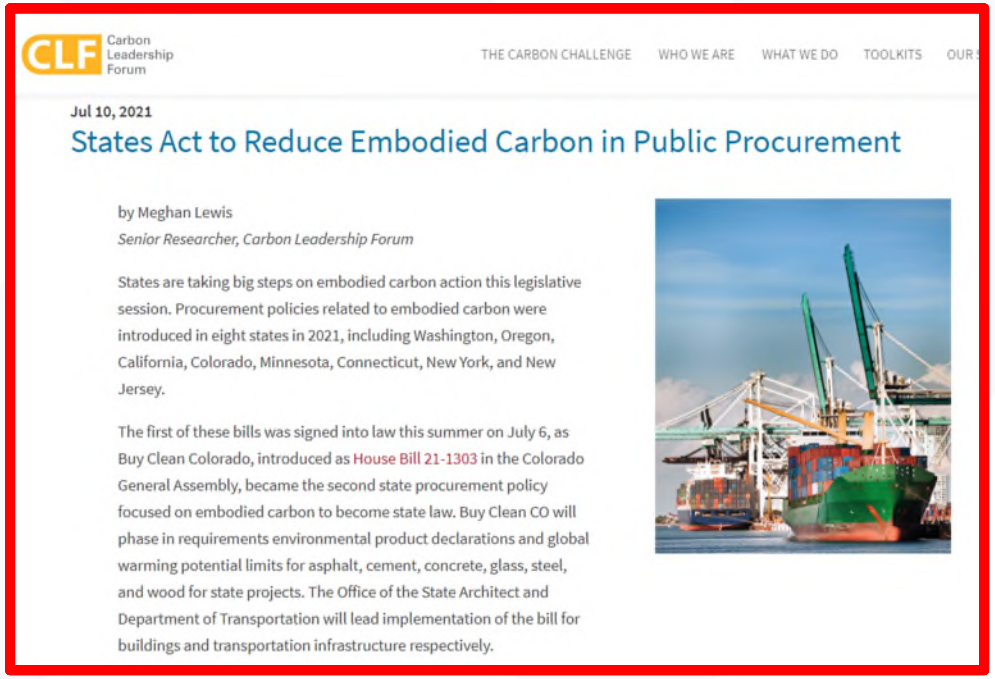
The "Code Requirements for Low-Carbon Concrete" ("Code") provides provisions for concrete where reduced global warming potential (GWP) is required. This code was developed by a consensus process and addresses cast-in-place concrete with specified compressive strength greater than 2500 psi and less than or equal to 8000 psi. Precast concrete, auger cast concrete, and shotcrete are not included in the scope of the Code. This is the first edition of the Code and the scope is limited by the available benchmark data. Future editions of the Code will be broader in scope as data beyond strength benchmarks and for other types of concrete becomes available.

The Code may be adopted as a stand-alone code or can be used in combination with a structural design code or low-carbon material code adopted by an authority having jurisdiction. The Code is in a format that allows reference to a set of chapters based on the structure type. Adoption would include all of Chapters 1-4, the applicable Chapter(s) of 5, 6, 7, and/or 8, plus Appendix A. The Code is written in a format that allows reference without change to its language. Therefore, background details or suggestions for carrying out the requirements or intent of the Code provisions cannot be included with the Code itself. The Commentary is provided for this purpose.

Some considerations of the committee in developing the Code are discussed in the Commentary along with references for the user desiring to study individual questions in greater detail.

State & Federal Regulatory-Driven Embodied Carbon Goals





Jul 10, 2021

States Act to Reduce Embodied Carbon in Public Procurement

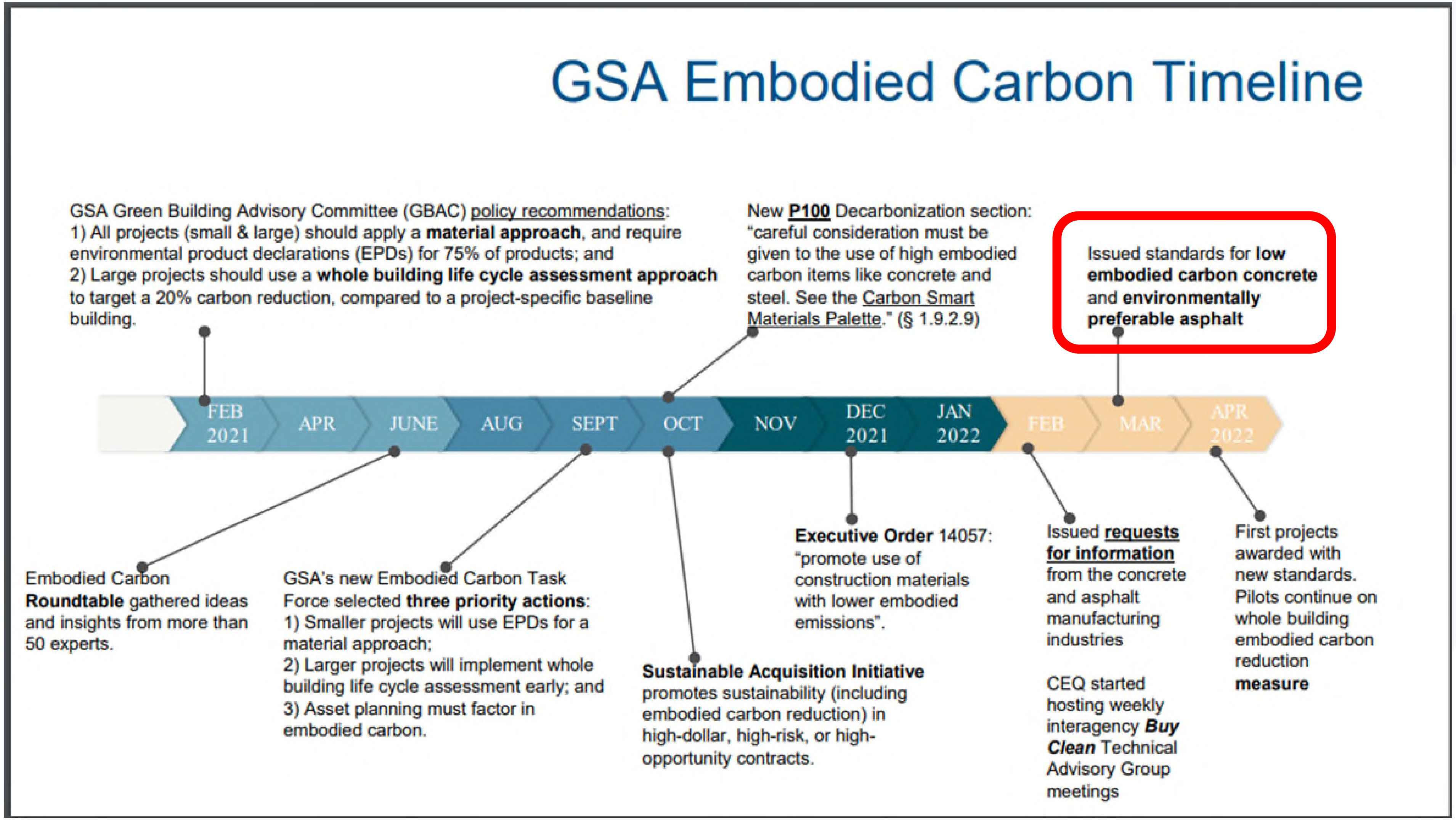
by Meghan Lewis
Senior Researcher, Carbon Leadership Forum

States are taking big steps on embodied carbon action this legislative session. Procurement policies related to embodied carbon were introduced in eight states in 2021, including Washington, Oregon, California, Colorado, Minnesota, Connecticut, New York, and New Jersey.

The first of these bills was signed into law this summer on July 6, as Buy Clean Colorado, introduced as House Bill 21-1303 in the Colorado General Assembly, became the second state procurement policy focused on embodied carbon to become state law. Buy Clean CO will phase in requirements environmental product declarations and global warming potential limits for asphalt, cement, concrete, glass, steel, and wood for state projects. The Office of the State Architect and Department of Transportation will lead implementation of the bill for buildings and transportation infrastructure respectively.

Should you be concerned???

GSA Embodied Carbon Requirements



Source: https://www.gsa.gov/cdnstatic/Horn_GBAC_Embodied%20Carbon.pdf

GSA Low Embodied Carbon Concrete Standards (2022)

	Maximum Global Warming Potential Limits for GSA Low Embodied Carbon Concrete (kilograms of carbon dioxide equivalent per cubic meter - CO_2e kg/m^3)		
Specified compressive strength (f'c in PSI)	**Standard Mix**	**High Early Strength**	**Lightweight**
up to 2499	**242**	**326**	**462**
2500-3499	**306**	**413**	**462**
3500-4499	**346**	**466**	**501**
4500-5499	**385**	**519**	**540**
5500-6499	**404**	**546**	**N/A**
6500 and up	**414**	**544**	**N/A**

These numbers reflect a 20% reduction from GWP (CO_2e) limits in proposed code language: "Lifecycle GHG Impacts in Building Codes" by the New Buildings Institute, January 2022.

Source: https://www.gsa.gov/cdnstatic/Horn_GBAC_Embodied%20Carbon.pdf

GSA IRA Low Embodied Carbon Concrete Requirements (2023)

	GSA IRA Limits for Low Embodied Carbon Concrete (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.			

Compliance Documentation

- A product-specific Type III (third-party verified) Environmental Product Declaration (EPD) that:
  - ✓ is based on the PCR used to develop these limits: NSF International's Product Category Rule for Concrete (8/2021, version 2.1); and
  - ✓ conforms with ISO 14025 and ISO 21930

Source: https://www.gsa.gov/system/files/Concrete%20-%20GSA%20IRA%20Low%20Embodied%20Carbon%20Requirements%20%28Dec.%202023%29_508.pdf

GSA IRA Low Embodied Carbon Concrete Requirements (2023)

CLF Carbon Leadership Forum

« Back to News and Features

February 13, 2024

GSA Low Carbon Materials Funding

GSA Announces 150+ Projects with $2 billion in Funding for Clean Construction Materials

Primary Authors: Meghan Lewis (Carbon Leadership Forum), Walter Tersch (GSA), Katie Poss (Building Transparency)

In August 2022, the historic **Inflation Reduction Act** (IRA) Section 60503 appropriated $2.15 billion of funding to the U.S. General Services Administration (GSA) to procure substantially lower embodied carbon (LEC) construction materials for use in federal building and paving projects. This funding builds on GSA's P100 Facilities Standards for concrete and asphalt (sections **4.8.5 and 4.8.6**) and 20% whole-building embodied carbon reduction (**P100 section 1.9.2.9**), along with information gained through the interagency **Federal Buy Clean Initiative**. GSA's new low-carbon material requirements – together with the Department of Transportation's upcoming **Low-Carbon Transportation Materials Grants Program** – advances progress towards the federal sustainability goal to reach **net-zero emissions procurement by 2050**.

Winning GSA project bids without low embodied carbon materials will be tough

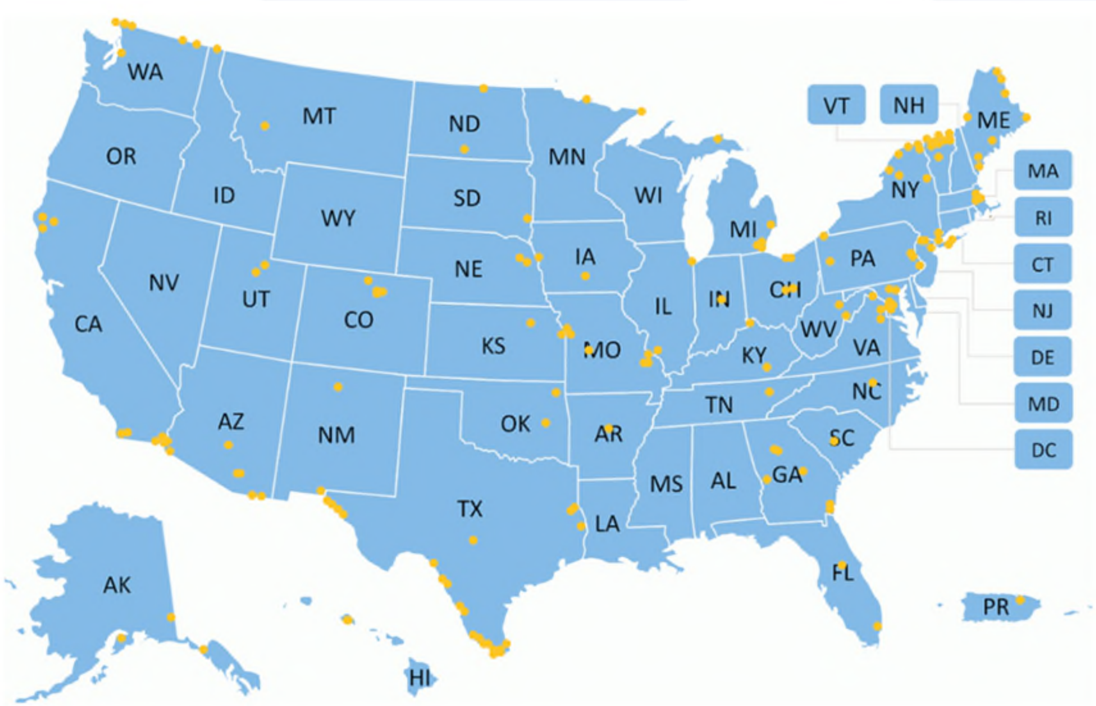
In December 2023, GSA published a **map of over 150 projects** around the country that will now be eligible for using IRA funding for low embodied carbon (LEC) materials. GSA also put together a handy list of materials for each project **here**.

For these 150 planned IRA LEC projects, securing low-carbon products is critical for contractors to receive awards. GSA's initial IRA solicitations have employed best value selection procedures that include environmental attributes — including a Sustainability factor that evaluates whether proposals include low carbon materials in as many relevant product subcategories as possible — in addition to price.

If contractors cannot provide concrete, steel, glass, and asphalt materials that are at least better (lower-carbon) than average, their proposals may be considered non-responsive and ineligible for award.

Source: https://carbonleadershipforum.org/gsa-funding-clean-construction/

https://www.gsa.gov/real-estate/gsa-properties/inflation-reduction-act/lec-program-details/lowembodied-carbon-projects

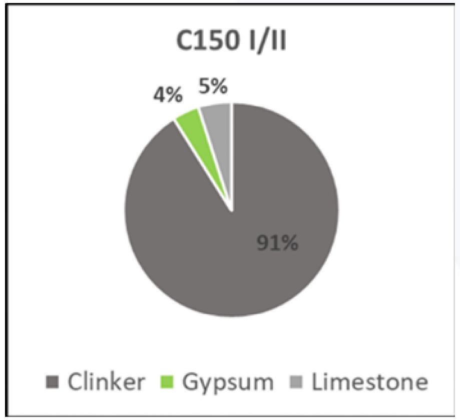


Specifications for Low-Embodied Carbon Concrete (LECC)

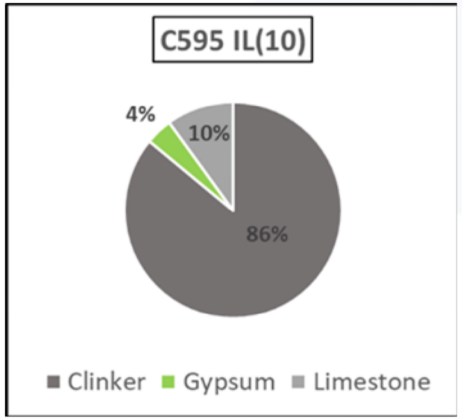
- Global Warming Potential (GWP) limit will most likely be specified in addition to compressive strength.
  - Third-party verified Product Specific Type III EPD in accordance with ISO 14025 must be submitted.
- Other performance requirements might be specified.
- **Should not:**
  - limit type of cement that can be used
  - place limits on cement content
  - limit SCM contents (except F3 Exposure)
  - limit w/cm, if not needed
- **Should consider** an acceptance age for strength beyond 28-days.
  - 56-days or later

Barriers in specifications <u>must</u> be eliminated.

Use RFIs, if necessary



The Era of PLCs (Type I L Cement)



Use of Blended Cements in U.S.

You are here › Home › 2024 › April › 2 › PCA: All state DOTs on board with portland-limestone cement

PCA: All state DOTs on board with portland-limestone cement

April 2, 2024 Concrete News

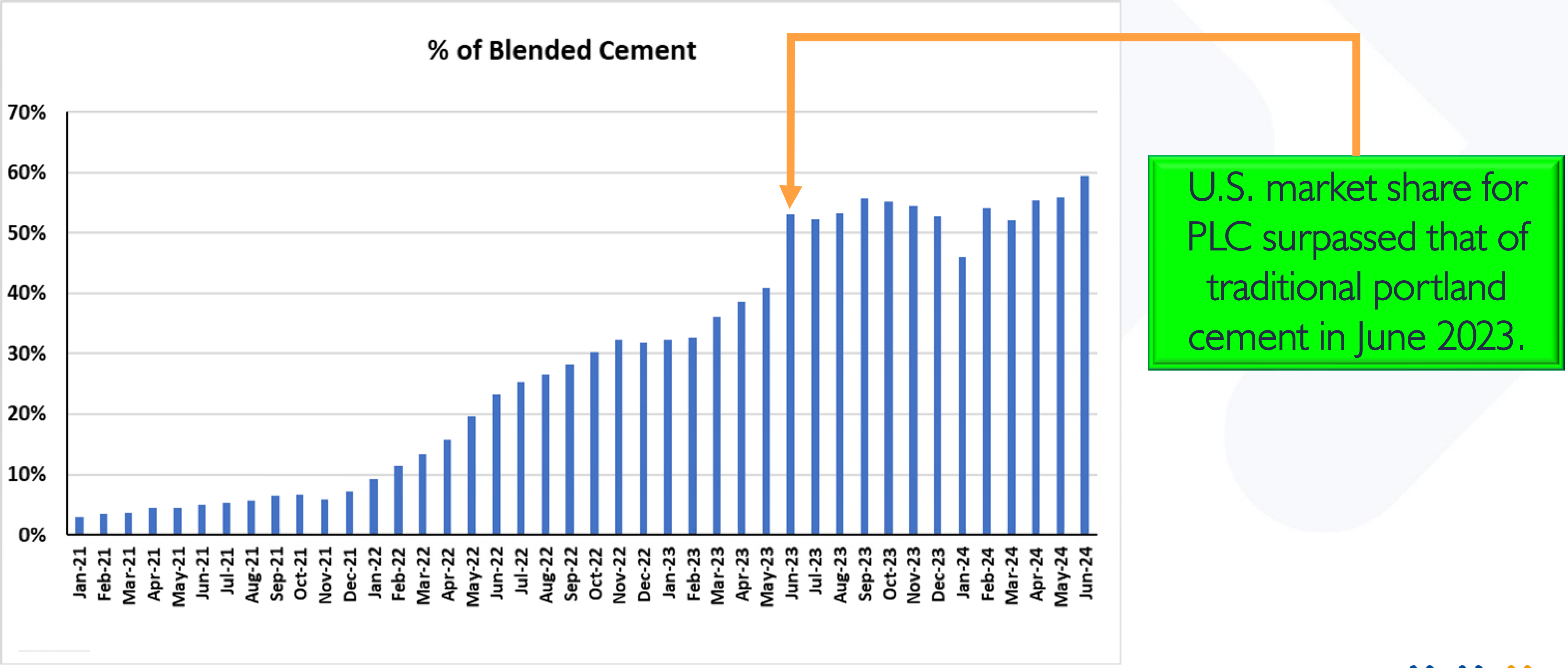
Sources: Portland Cement Association, Washington, D.C.; CP staff

On the heels of a Connecticut Department of Transportation green light, Portland Cement Association reports universal state agency approval of portland-limestone cement, or ASTM C595 Type IL binder. Measured against ASTM C150 Type I/II portland cement, PLC is finished with higher limestone content, while exhibiting a carbon dioxide emissions footprint up to 10 percent lower. PCA estimates that in 2023, U.S. cement producers avoided emitting more than 4 million metric tons of CO_2 by incorporating PLC and other blended cement alternatives. The 50-state plus District of Columbia Type IL approval milestone coincides with transportation agencies—key cement and concrete users in the overall public construction arena—increasing material consumption as Infrastructure Investment and Jobs Act funding drives higher than normal levels of road and bridge work.

PLC now approved by all 50 State DOTs

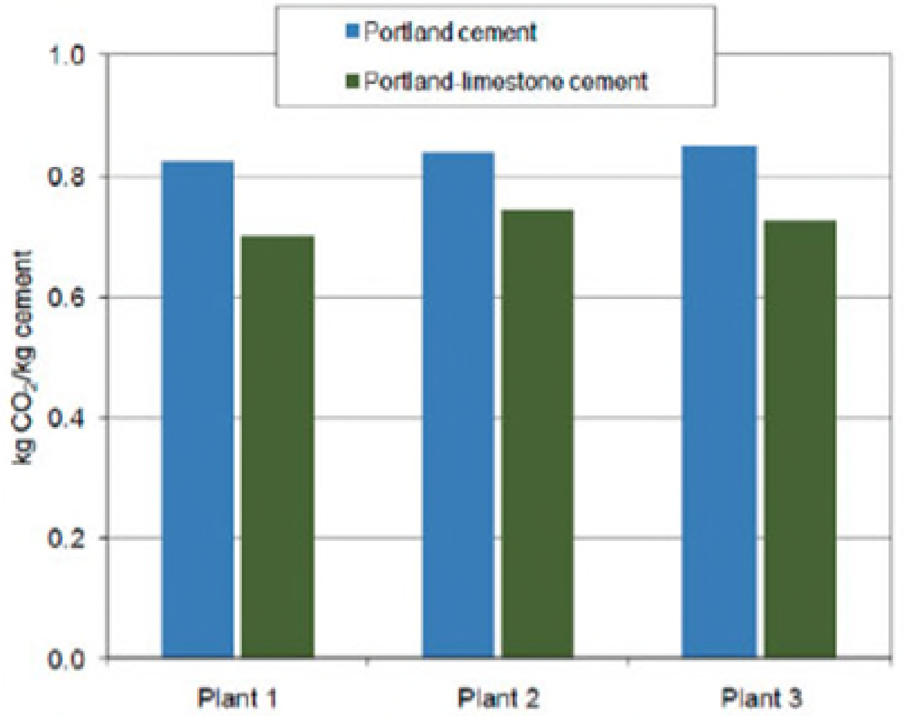
https://concreteproducts.com/index.php/2024/04/02/pca-all-state-dots-on-board-with-portland-limestone-cement/

Use of Blended Cements in U.S.



Environmental Benefit of PLC

Table 2



Specific CO_2 emissions from the production of portland cement or portland-limestone cement for three German cement plants (adapted from Schmidt 1992).

https://www.concreteconstruction.net/how-to/concrete-production-precast/the-advantages-of-portland-limestone-cement_o

Up to
10% reduction
in GWP

PCA Industry Average EPD	
Type of Cement	GWP (kg CO_2 eq)
Type I/II	925
Type IL	855

PLCs are the "Hot Topic" in the Concrete Industry Today!

Guidance for Concrete Contractors ... #14 in a Series

✔ Posted on February 15, 2023 in: Technical

Jim Klinger, The Voice Newsletter February 2023

Full Disclosure: Over the past year, the ASCC Technical Division fielded several Hotline calls from members experiencing difficulties related to ASTM C 595 portland-limestone cement Type1L, hereinafter referred to as "PLC" (as opposed to "OPC", ordinary portland cements, brand X,ASTM C 150 Types I and I/II and so on).

Question: What are the typical problems with PLC being reported from the field by ASCC concrete contractors today?

Answer: According to our recent survey, suspected side effects of added limestone include increased water demand, slow set time (need for adding accelerator admixtures), low strength, crusting of top surface, more shrinkage cracks, more labor required to finish. Anecdotal reports of problems with sawcutting and adhesives not sticking are being vetted by the ASCC Technical Division. Longer-term issues with durability (e.g. wear resistance, polishing issues) are being investigated as well. To date, no issues with shotcrete applications were reported.

https://ascconline.org/Home/News/articleType/ArticleView/articleId/325/Guidance-for-Concrete-Contractors-14-in-a-Series

Slower setting, low strength, cracking & other issues have been reported.

Not all Type IL Cements are the same!

The Design Professional's Role

- Structural Efficiency
- Durability
- Sustainability
- Resiliency
- Constructability

Southbank, Chicago Project Specification

Embodied Carbon Specific Clause – Concrete

Embodied Carbon

Embodied Carbon

The Subcontractor shall work closely with Lendlease to provide low embodied carbon products and solutions. The requirements extend to the materials used in the manufacturing of products that are required and form part of the installation to complete the scope of works.

In the pursuit of minimising embodied carbon within the Southbank Building E development, Lendlease is committed to maximising the extent of recycled content utilised within specified construction materials. Portland cement content in concrete mixes are a key factor in the building's overall embodied carbon, and therefore a high percentage of supplementary cementitious materials are required. All concrete mixes proposed shall not exceed the cradle to gate emissions in the below table for the associated strengths. Cradle to gate is defined as modules A1-A3 under the EN15804 system boundary.

Strength	kgCo2e/yd3
2500 psi	149
3000 psi	164
4000 psi	200
5000 psi	242
6000 psi	254
8000 psi	294

The Subcontractor is required to provide the following for each product or group of products to be supplied:

- A Life Cycle Assessment (LCA), prepared in accordance with ISO14040 and ISO14044, with results presented based on the following impact category: Global Warming Potential (GWP 100yr);
- An Environmental Product Declaration (EPD), prepared in accordance with ISO14025, with results presented based on at least the following impact category: Global Warming Potential (GWP 100yr);

Project Specification vs. Contractor's Performance Needs!

Specification Mix Type	Test Age Days	UM	Takeoff Quantity
3000 Mud Slab	28	cy	76.00
4000	28	cy	392.63
4000 AE	28	cy	322.43
6000 FDN	28	cy	405.30
6000 MASS FDN	28	cy	236.13
6000 COLS/SW/WALLS	56	cy	1,117.05
6000 AE WALLS/COLS EXP	28	cy	861.95
6000 SLABS PT/BM/STAIRS	28	cy	680.22
6000 AE GRG SLABS/BM/STAIRS	28	cy	3,611.26
8000 MASS FDN	28	cy	980.10
8000 SLABS PT/BM/STAIRS	28	cy	12,441.08
8000 AE SLABS	28	cy	98.09
8000 COLS/SW	56	cy	681.08
10000 COLS/SW	56	cy	6,373.13
TOTALS			28,276.45

Strength	kgCo2e/yd3
2500 psi	149
3000 psi	164
4000 psi	200
5000 psi	242
6000 psi	254
8000 psi	294

- Slump Retention
- Initial Finishing
- Final Finishing
- Form Stripping

Here are the requirements of what McHugh typically requires. This is taken straight from their PO. This is for all of their jobs. Let me know if you have any questions

Seller will provide mixes that are workable, placeable and pumpable. Any alteration or modification to the mix designs necessary to achieve the requirements described herein in addition to field requirements not described herein are included. McHugh shall provide pumping and placing equipment that is adequate for its intended purpose and shall provide available information relative to the equipment to Seller if requested.

Seller guarantees that concrete will be delivered at a minimum slump of 6.5" at the point of placement in the form. Seller includes additional superplasticizer or any other additives or changes to the mix as required to achieve such slump. Seller acknowledges that it is the intention of McHugh to place the majority of the concrete with pumps and placing boom.

Seller is aware of McHugh's scheduling requirements including, but not limited to the requirements that McHugh be able to be perform initial finishing (floating) in 2 hours, and final finishing (troweling) in 4 hours after the commencement of a slab pour without damaging the slab. Seller shall adjust the mixes at no cost to McHugh and in a manner selected by Seller and acceptable to McHugh, to conform to these scheduling requirements. The mix adjustments include the use of non-chloride accelerating admixtures at no additional cost to McHugh only if necessary to meet these scheduling requirements. To the extent that deliveries are not made at the requested delivery rate, the mix shall be adjusted to reduce the four hour duration as necessary to allow layout and forming activities to begin on schedule.

Seller is aware that it is the intention of the McHugh to strip forms from vertical elements including, but not limited to columns and walls, starting at 6am the morning after the pour and that these elements will generally be poured the afternoon prior to stripping. Seller includes adjustments to the mixes as required to meet these criteria.

Low-Embodied Ca[...]rete Project Specifica[...] consider C[...]equirements

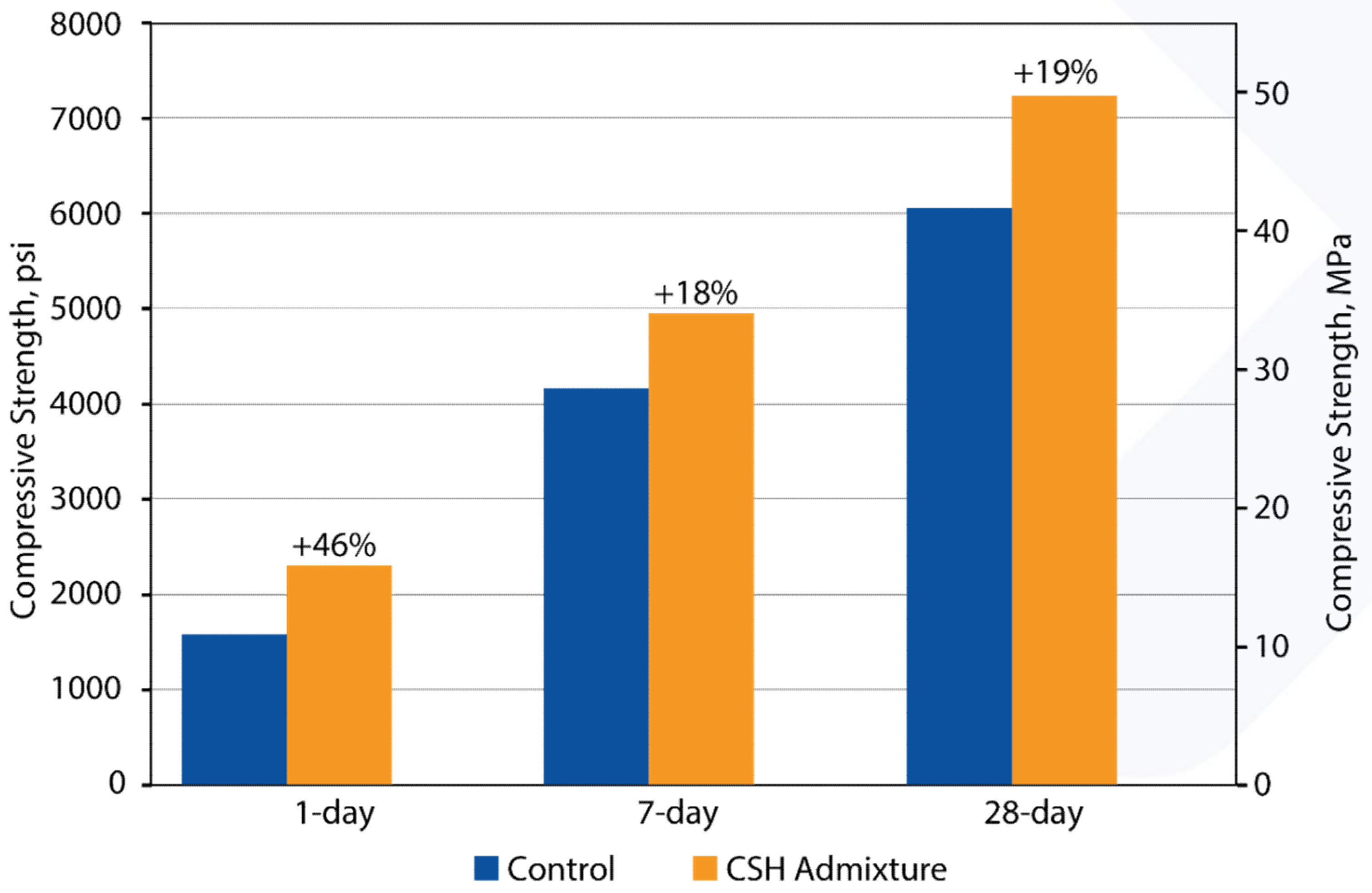
Constructability!!!

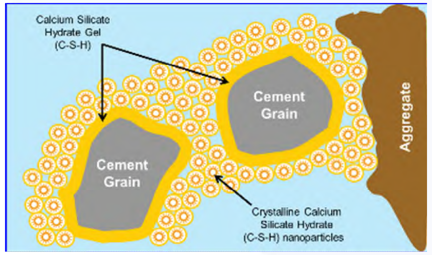
Perform Trials to Evaluate PLCs / LECCs & Identify Potential Issues!

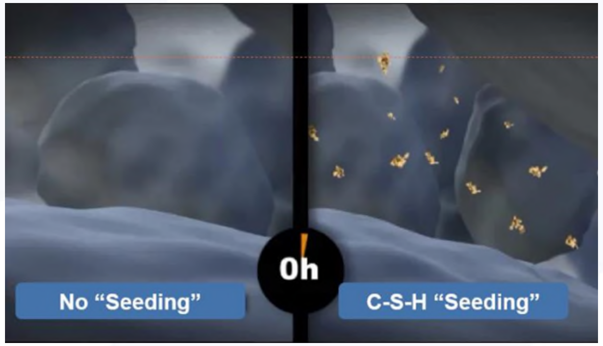
Admixture Solutions for Low-Embodied Carbon Concrete (LECC)

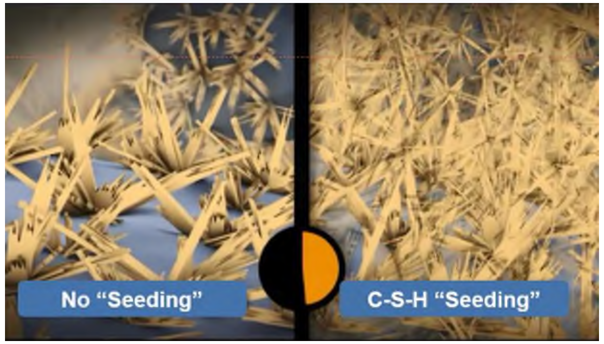
- Accelerating Admixtures (or Retarding Admixtures)
- C-S-H Nanoparticle Strength-Enhancing Admixtures
- Rheology Modifying Admixtures
- Hydration-Stabilizing Admixtures
  - 90-minute rule is gone!
  - ASTM C1798 permits reuse of returned fresh concrete

C-S-H Strength-Enhancing Admixture (SEA)



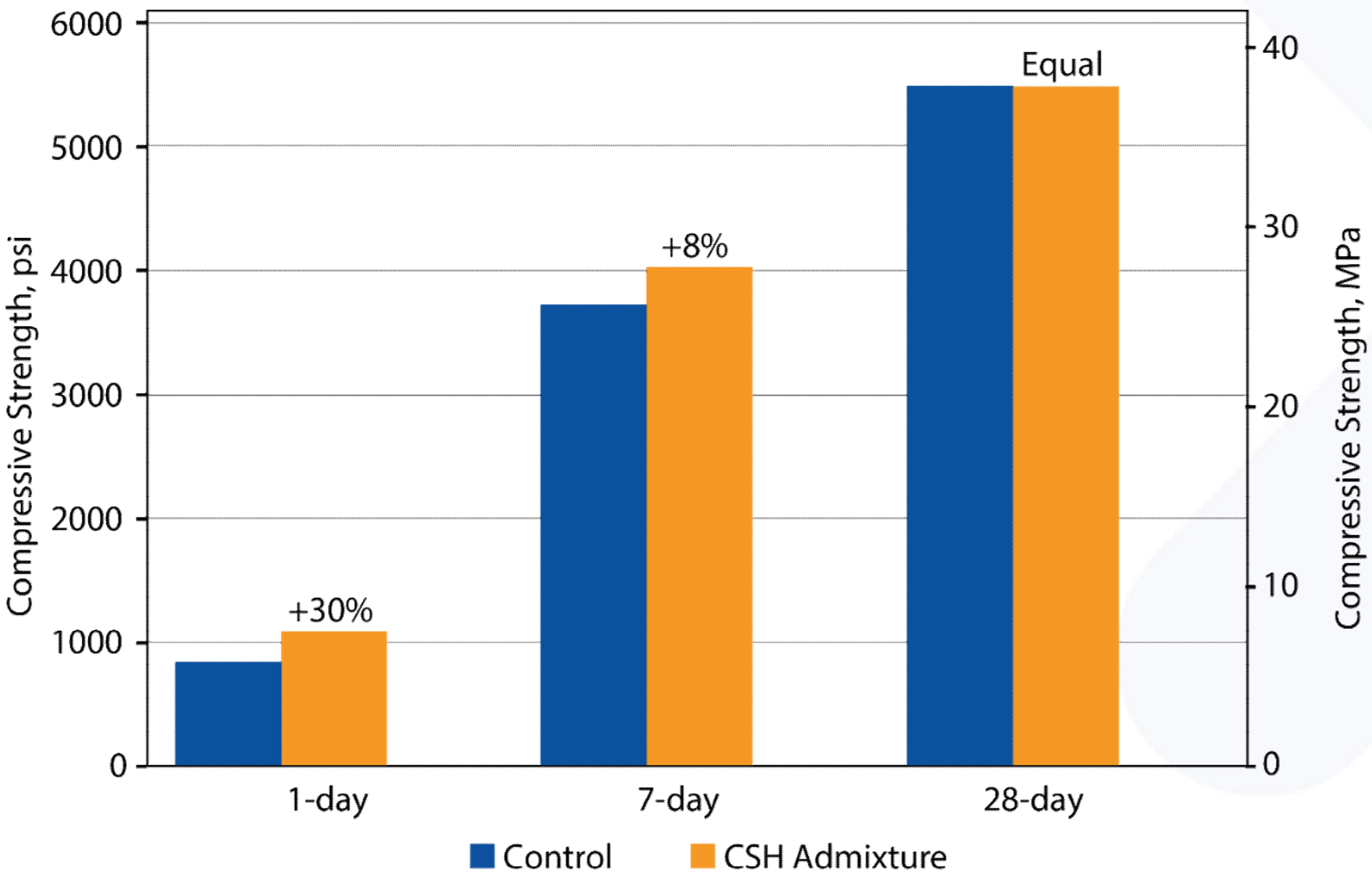


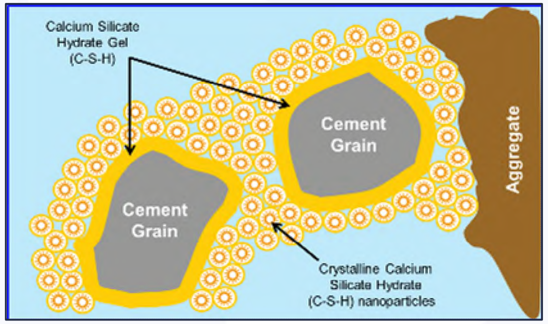




(Nominal cementitious materials content of 611 lb/yd^3 [362 kg/m^3] with 20 percent fly ash, w/cm of 0.47; CSH-based Strength-Enhancing Admixture dosage of 10 fl oz/cwt [650 mL/100 kg])

C-S-H Strength-Enhancing Admixture (SEA)



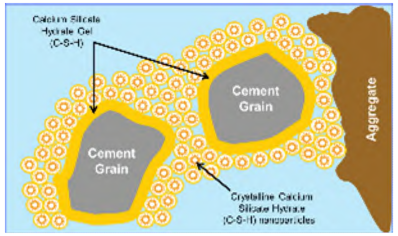


Benefits:

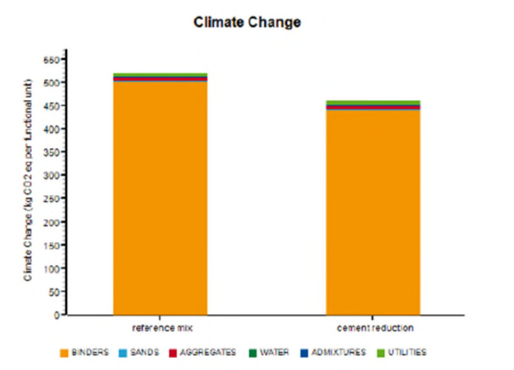
- Jumpstarts hydration process.
- Enhances early- & late-age strength development.
- Permits reduction in portland cement content and/or use of increased replacement levels of SCMs.
  - direct reduction in embodied carbon of concrete

Control: Total binder content - 705 lb/yd^3 [418 kg/m^3] with 25% fly ash, 21% limestone powder, 0.39 w/cm;
C-S-H Admixture: Dosage of 7.3 fl oz/cwt [475 mL/100 kg], Total binder content - 629 lb/yd^3 [373 kg/m^3] with 25% fly ash, 21% limestone powder, w/cm of 0.40

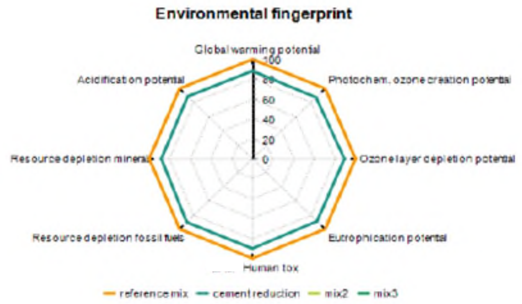
SEA Application: Pier 27 Residential Building - Toronto, Canada



- 35-storey residential building completed Summer 2019;
- ~ 32,700 yd^3 (25,000 m^3) of concrete;
- 3,900 yd^3 (3,000 m^3) of concrete optimized to achieve high-early strength in 16 – 18 h;
  - lower cementitious materials content
  - workable and pumpable; slump loss minimized
- Received the "Material Development & Innovation Award" from Ontario Concrete Awards in Dec. 2019.



Overall reduction in environmental footprint



SEA Application: 100 Above the Park, St. Louis

https://liveat100.com/?utm_source=Google.com&utm_medium=Other&utm_campaign=GoogleMyBusiness&utm_content=Website&utm_term=Button&rdnaLabel=GoogleMyBusiness

Owner: **MAC Properties**

Location: **St. Louis, MO**

Architect: **Studio Gang Architects**

Engineering Firm: **Magnusson Klemenic Associates**

General Contractor: **Clayco**

Concrete Contractor: **Concrete Strategies, LLC**

Concrete Supplier: **Kienstra Co.**

PT Concrete Mixture: **3K @ 24 hours; 7.5K @ 28 days**

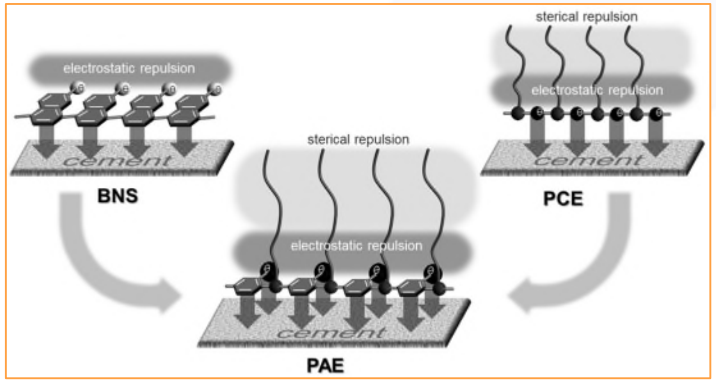
https://www.concrete.org/aboutaci/honorsandawards/awards/projectawards/pastwinners/2022.aspx

SEA Application: Concrete Paving

- Hwy 287 Roadway Rehabilitation
- J Lee Milligan, Inc. – Producer and Contractor
- TXDOT Project: 2019 - 2020
- Donley County, Hedley TX
- 16,000 yd^3
- Two phases of 11" Continuously Reinforced Concrete Paving (CRCP)
- Standard slip-formed 2" slump mixture with 458 lb/yd^3 of portland cement and 3.5% air content achieved breaks of 3200 psi in about 3 - 4 days
- SEA addition eliminated fly ash to avoid availability issues

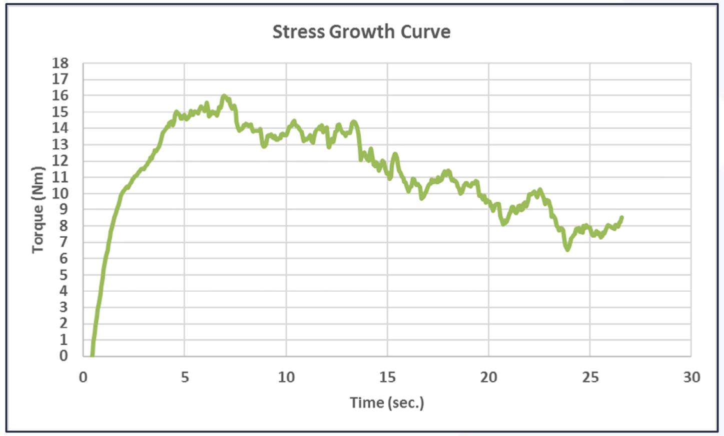
Rheology Modifying Water-Reducing Admixtures

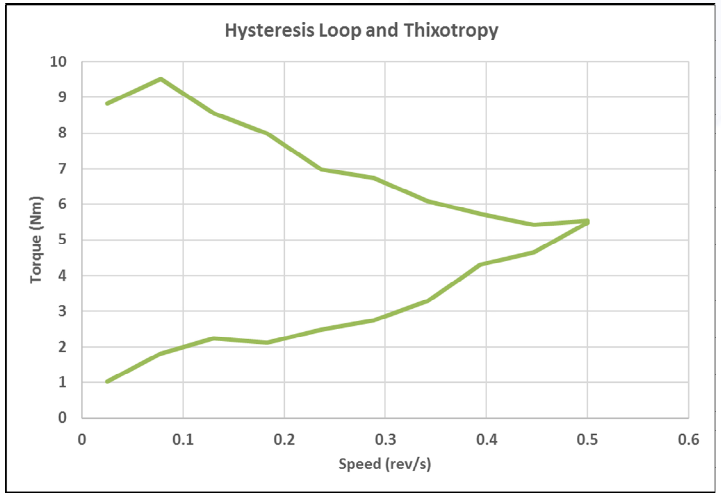
…for production of high-performance concretes with low viscosity.



Rheology Modifying Water Reducers for Low-Viscosity Concretes

Rheological parameters determine how materials flow and move…





Measured Parameters
- Static yield stress
- Dynamic yield stress
- Plastic viscosity
- Thixotropy

Concrete Properties Impacted
- Workability
- Stickiness/feel
- Filling capacity
- Passing ability
- Mixture stability
- Pumping
- Placing
- Handling
- Finishing

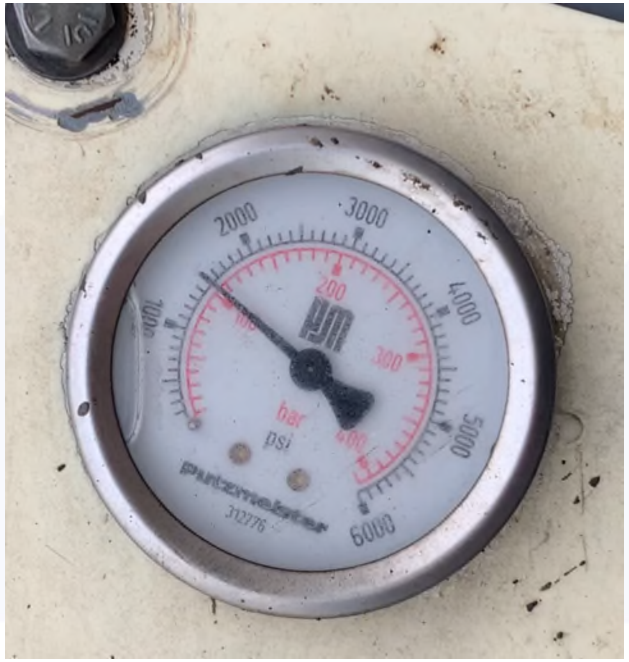
Response to Pumping

Pump Pressure Reduced by ~20%

2,400 psi

Standard Type 1L Concrete Mixture

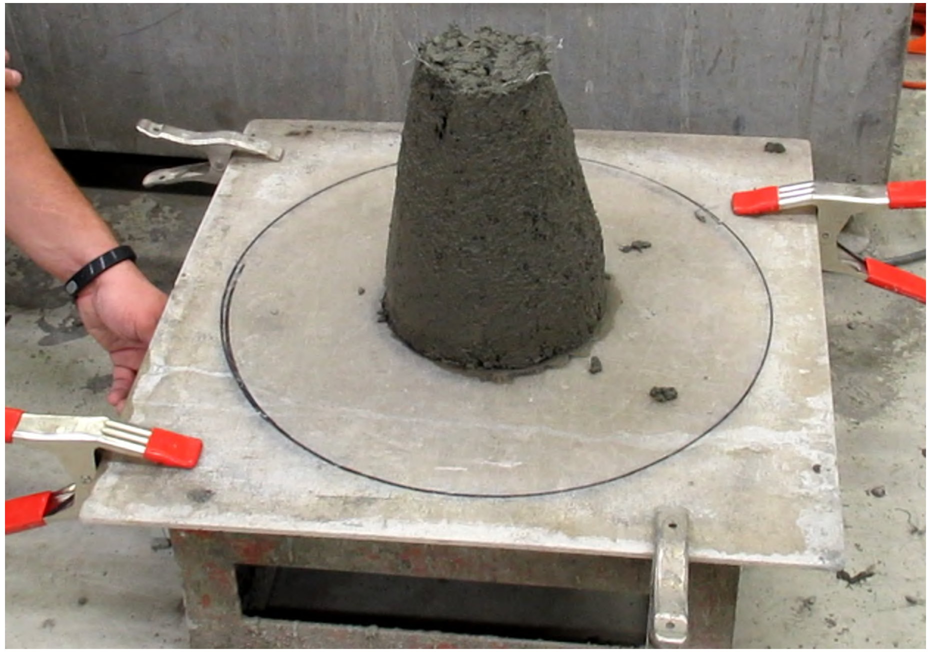
2,000 psi



with RM Type A Admixture

Response to Energy of Vibration

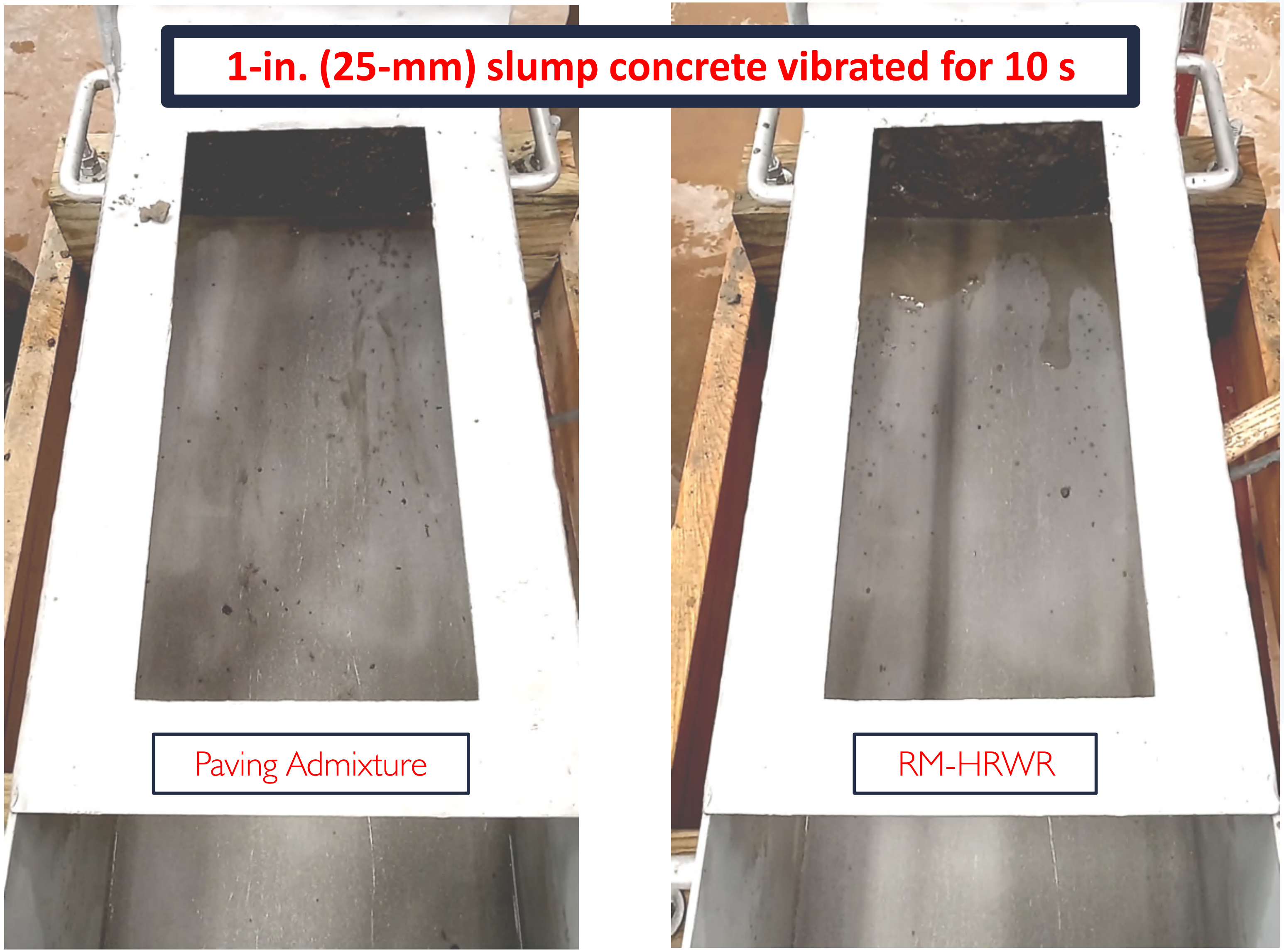
Identical 4-in. (100-mm) slump FRC concrete mixtures vibrated for 10 s.

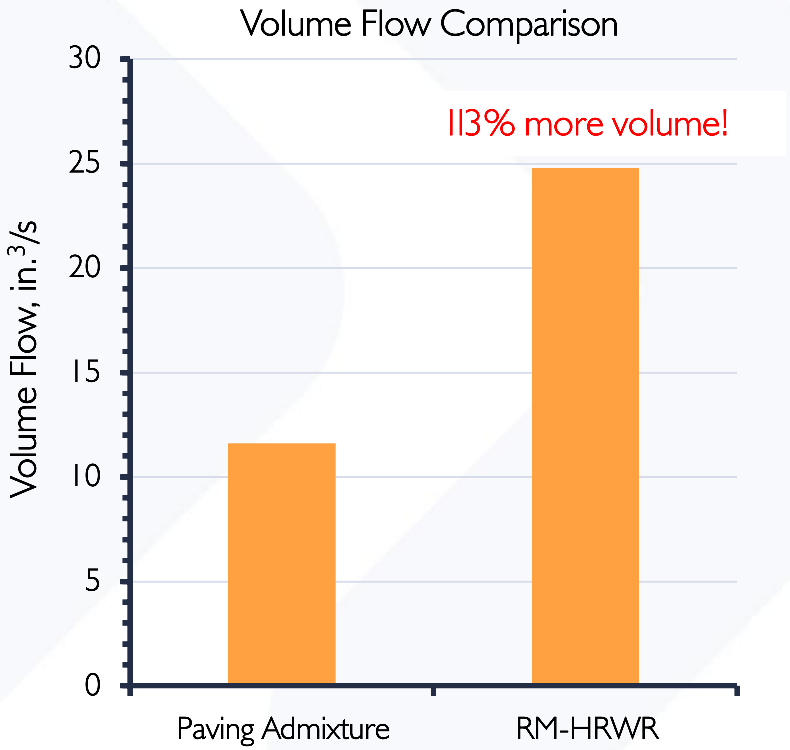


Lignin-based MRWR

RM Type A Admixture

Quantifying Response of RM Admixture to Vibration





Customer / Contractor Feedback

- Interviews with paving contractor:
  - "Noticeable difference on the edges – crispness and sharpness; it held the edge very well"
  - "No issues with low-slump concrete; possible to consolidate zero-slump concrete."
  - "Noticeable better aggregate distribution in core sample → possibility to reduce segregation."
  - "Anticipated benefit with the use of difficult materials"

RM Admixture Benefits

Reference Type I L Mix

Solution for Harsh and Sticky Concrete Mixtures

- Extruded much easier
- Improved Flow
- Reduced Energy Use
- Smoother finish with noticeably fewer voids and imperfections

RM Admixture Mix

Synergistic Performance

Improved placement (and strength)

- Improved surface finishing
- Faster placement in paving machine
- Higher early strengths without accelerating time of set
- Earlier opening to traffic
- Ability to utilized lower quality aggregates
- Possible improved air-void with MasterEase
- Lower w/cm ➔ improved durability
- Cost savings with cement reduction
- Lower CO_2 footprint with cement reduction

In Summary…

Prescriptive- vs. Performance-Based Concrete Specifications

Prescriptive:

- Defines a concrete mixture in terms of its constituents and is a means to an end.
  - Minimum cementitious materials content
  - Maximum w/cm
  - Air content
  - Slump
  - **Verified**
- Doesn't guarantee required performance.
- **Hinders innovation!**

Performance:

- Defines a concrete mixture in terms of measurable plastic and hardened properties.
- The end is verified by measuring the specific concrete properties.
- Test methods and acceptance criteria must be clearly defined!
- **Promotes Innovation**

Use RFIs if specification requirements are unclear!

Specifications for Low-Embodied Carbon Concrete (LECC)

- Global Warming Potential (GWP) limit will most likely be specified in addition to compressive strength.
  - Third-party verified Product Specific Type III EPD in accordance with ISO 14025 must be submitted.
- Other performance requirements might be specified.
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  - limit SCM contents (except F3 Exposure)
  - limit w/cm, if not needed
- **Should consider** an acceptance age for strength beyond 28-days.
  - 56-days or later

Barriers in specifications must be eliminated.

Develop EPDs for your Mixes!

Performance-Based Specifications: Concrete Mixture

Concrete Mixture:

- Strength (compressive / flexural)
- Modulus of Elasticity (MOE)
- Permeability or Transport Properties
  - RCPT (ASTM C 1202)
  - Chloride Diffusion Coefficient
  - Resistivity
- Volume Change
  - Cracking
- Chemical Reaction
  - Alkali-Silica Reaction (ASR)
- **GWP**
  - 3rd-Party Verified Type III EPD

Property	Test Method
Compressive Strength	ASTM C 39
Flexural Strength	ASTM C 78
Modulus of Elasticity	ASTM C 469
Permeability:	
• RCPT	ASTM C 1202
• Chloride Diffusion Coefficient	ASTM C 1556
• Surface Resistivity	AASHTO T 358
• Bulk Electrical Resistivity	ASTM C 1876
Volume Change:	
• Drying Shrinkage	ASTM C 157
• Time to Cracking	ASTM C 1581
Chemical Reaction:	
• Alkali-Silica Reaction (ASR)	ASTM C 1260, C 1567, C 1293

Plan Ahead!

- Time
- May require specialized testing and expertise
- Cost

A Balance is Needed!

Low-Embodied Carbon Concrete Project Specifications should consider Contractor Requirements

- Slump Retention
- Initial Finishing
- Final Finishing
- Form Stripping
- Post Tensioning
- Strength Development

For a Successful Low-Embodied Carbon Concrete Project…

Collaboration is required among all parties!

Thank You!

Questions

Dr. Charles Nmai, PE, M.ASCE, FACI
Master Builders Solutions US Admixtures, LLC
Email: charles.nmai@masterbuilders.com