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Pushing the Boundaries on Low Carbon Concrete at San Francisco International Airport

Concrete Innovations Session #23

Frances Yang

August 21, 2024

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Timeline

2012	LEEDv4 released
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2023	SFO Bus Maintenance Facility Pilot
2024	Concrete Innovation Award LCC update in SFO SPDC Guidelines

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Acknowledgments

SFO Terminal 1 Boarding Area B

- Anthony Bernheim, SFO*
- Crystal Barriscale & Andrew McCune, HKS
- Jamie Curry, Rutherford & Chekene
- Wayne Campbell, Austin-Webcor
- Central Concrete

Bay Area Low Carbon Concrete Code

- Bruce King, EBNet
- Bill Kelly & Alice Zanmiller, Marin Co.
- Kate Simonen, CLF
- Miya Kitahara, StopWaste

SEAONC Concrete Mix Designs Project

- Megan Stringer, Holmes
- Nick Miley, KPFF
- Ana Maura Cook, Arup

SFO SPDC Guidelines

- Erin Cooke, SFO
- Raphael Sperry, Arup
- Christine Tiffin, Arup
- Youngbo Shim, Arup

***content on slides with blue banner is from SFO**

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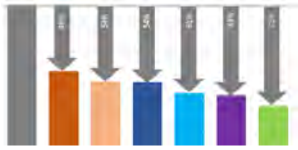
SFO Sustainability Goals for T1

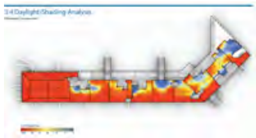
ACHIEVE LEED V4 GOLD



DEFINE PATH TO ZERO ENERGY

TRIPLE-BOTTOM-LINE: QUANTIFY ECONOMIC, SOCIETAL AND ENVIRONMENTAL BENEFITS

UNDERSTAND THE WHOLE BUILDING CARBON FOOTPRINT



MASTER NATURAL LIGHT: OPTIMIZE DAYLIGHT, MINIMIZE GLARE

EXPANDED REQUIREMENTS CATEGORY
A Energy and Atmosphere
B Comfort and Health
C Water and Wastewater
D Site and Habitat
E Materials and Resources
F Equity and Aesthetics
G Stretch + REACH Goals

PURSUE EXPANDED REQUIREMENTS

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Environmental Impacts of California Concrete Mix Designs

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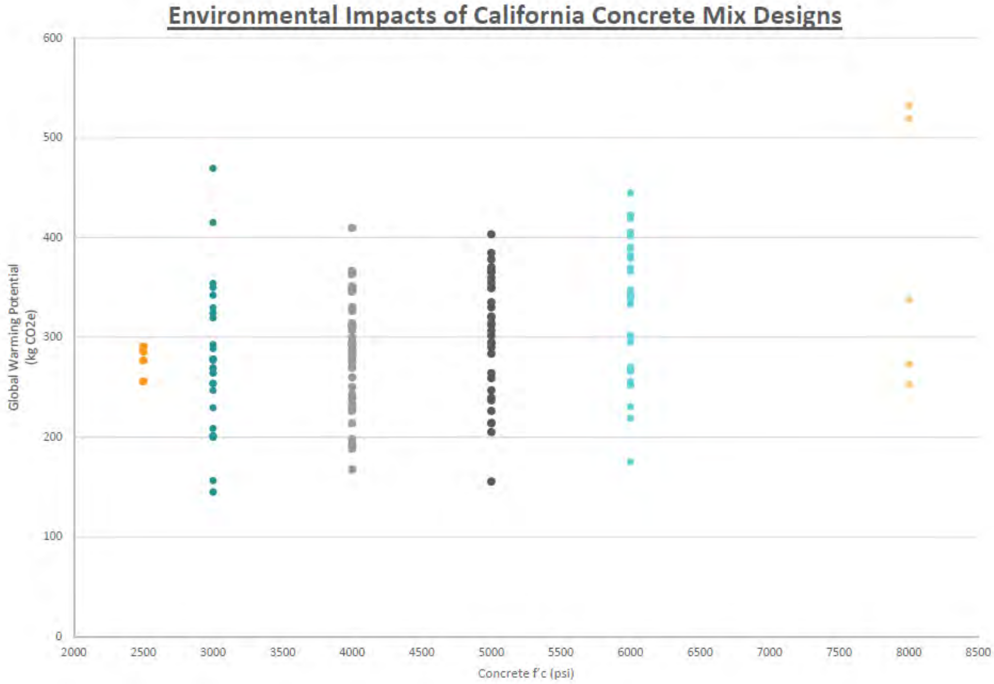

STRUCTURAL ENGINEERS ASSOCIATION NORTHERN CALIFORNIA SEA

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Problem with Recycled Content

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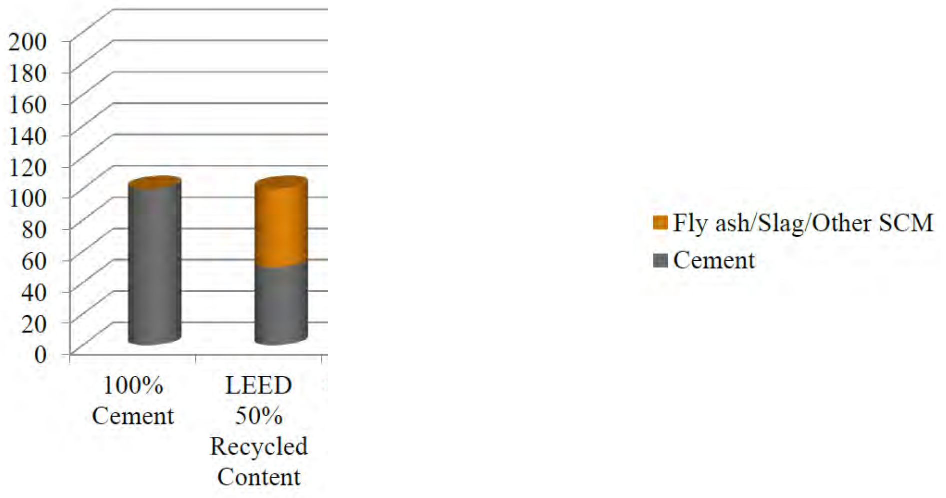

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Problem with Recycled Content

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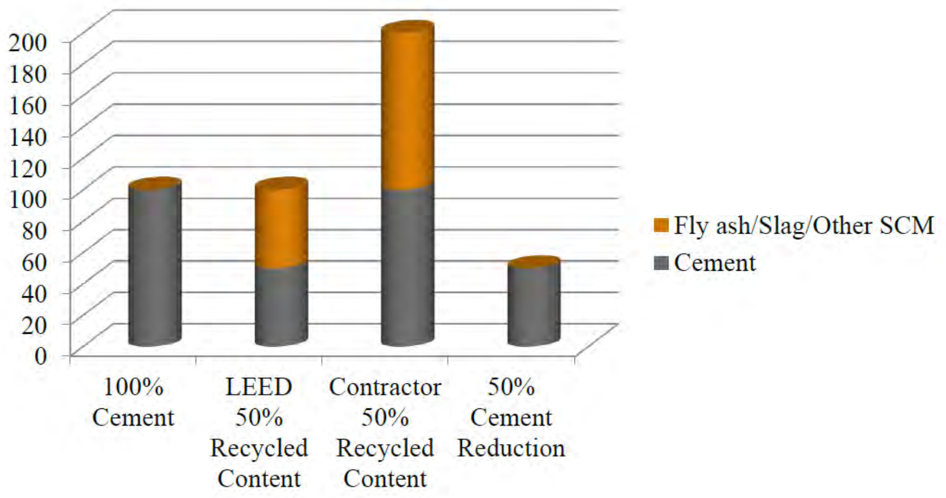

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Project Precedents

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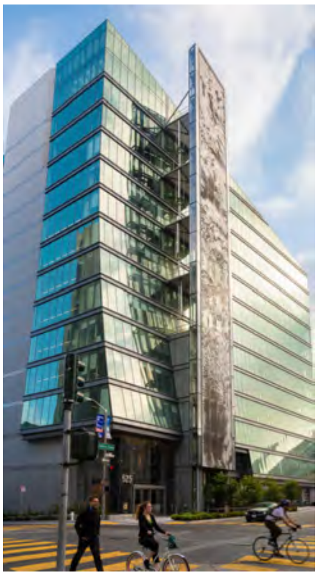

From left:
David Brower Center, Tipping Mar
SF PUC / 555 Golden Gate, Tipping Mar
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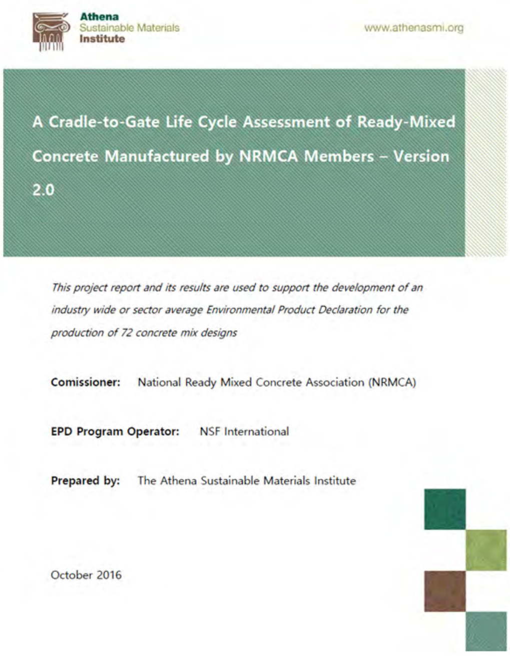

Athena Sustainable Materials Institute www.athenasmi.org

A Cradle-to-Gate Life Cycle Assessment of Ready-Mixed Concrete Manufactured by NRMCA Members – Version 2.0

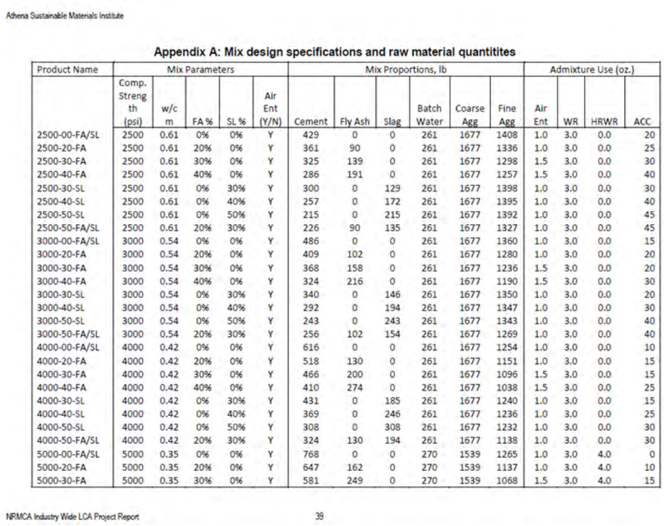
This project report and its results are used to support the development of an industry wide or sector average Environmental Product Declaration for the production of 72 concrete mix designs

Comissioner: National Ready Mixed Concrete Association (NRMCA)

EPD Program Operator: NSF International

Prepared by: The Athena Sustainable Materials Institute

October 2016


Athena Sustainable Materials Institute

Appendix A: Mix design specifications and raw material quantitites

Product Name	Mix Parameters					Mix Proportions, lb						Admixture Use (oz.)			
	Comp. Strength (psi)	w/cm	FA %	SL %	Air Ent (Y/N)	Cement	Fly Ash	Slag	Batch Water	Coarse Agg	Fine Agg	Air Ent	WR	HRWR	ACC
2500-00-FA/SL	2500	0.61	0%	0%	Y	429	0	0	261	1677	1408	1.0	3.0	0.0	20
2500-20-FA	2500	0.61	20%	0%	Y	361	90	0	261	1677	1336	1.0	3.0	0.0	25
2500-30-FA	2500	0.61	30%	0%	Y	325	139	0	261	1677	1298	1.5	3.0	0.0	30
2500-40-FA	2500	0.61	40%	0%	Y	286	191	0	261	1677	1257	1.5	3.0	0.0	40
2500-30-SL	2500	0.61	0%	30%	Y	300	0	129	261	1677	1398	1.0	3.0	0.0	30
2500-40-SL	2500	0.61	0%	40%	Y	257	0	172	261	1677	1395	1.0	3.0	0.0	40
2500-50-SL	2500	0.61	0%	50%	Y	215	0	215	261	1677	1392	1.0	3.0	0.0	45
2500-50-FA/SL	2500	0.61	20%	30%	Y	226	90	135	261	1677	1327	1.0	3.0	0.0	45
3000-00-FA/SL	3000	0.54	0%	0%	Y	486	0	0	261	1677	1360	1.0	3.0	0.0	15
3000-20-FA	3000	0.54	20%	0%	Y	409	102	0	261	1677	1280	1.0	3.0	0.0	20
3000-30-FA	3000	0.54	30%	0%	Y	368	158	0	261	1677	1236	1.5	3.0	0.0	20
3000-40-FA	3000	0.54	40%	0%	Y	324	216	0	261	1677	1190	1.5	3.0	0.0	30
3000-30-SL	3000	0.54	0%	30%	Y	340	0	146	261	1677	1350	1.0	3.0	0.0	20
3000-40-SL	3000	0.54	0%	40%	Y	292	0	194	261	1677	1347	1.0	3.0	0.0	30
3000-50-SL	3000	0.54	0%	50%	Y	243	0	243	261	1677	1343	1.0	3.0	0.0	40
3000-50-FA/SL	3000	0.54	20%	30%	Y	256	102	154	261	1677	1269	1.0	3.0	0.0	40
4000-00-FA/SL	4000	0.42	0%	0%	Y	616	0	0	261	1677	1254	1.0	3.0	0.0	10
4000-20-FA	4000	0.42	20%	0%	Y	518	130	0	261	1677	1151	1.0	3.0	0.0	15
4000-30-FA	4000	0.42	30%	0%	Y	466	200	0	261	1677	1096	1.5	3.0	0.0	15
4000-40-FA	4000	0.42	40%	0%	Y	410	274	0	261	1677	1038	1.5	3.0	0.0	25
4000-30-SL	4000	0.42	0%	30%	Y	431	0	185	261	1677	1240	1.0	3.0	0.0	15
4000-40-SL	4000	0.42	0%	40%	Y	369	0	246	261	1677	1236	1.0	3.0	0.0	25
4000-50-SL	4000	0.42	0%	50%	Y	308	0	308	261	1677	1232	1.0	3.0	0.0	30
4000-50-FA/SL	4000	0.42	20%	30%	Y	324	130	194	261	1677	1138	1.0	3.0	0.0	30
5000-00-FA/SL	5000	0.35	0%	0%	Y	768	0	0	270	1539	1265	1.0	3.0	4.0	0
5000-20-FA	5000	0.35	20%	0%	Y	647	162	0	270	1539	1137	1.0	3.0	4.0	10
5000-30-FA	5000	0.35	30%	0%	Y	581	249	0	270	1539	1068	1.5	3.0	4.0	15

NRMCA Industry Wide LCA Project Report 39

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Collaborative Process

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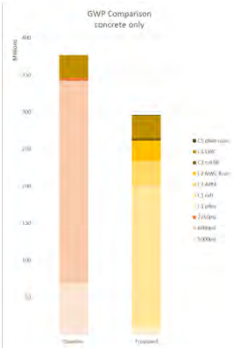
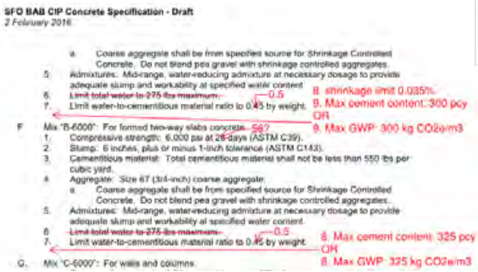
Step 1 - Determine Project Mix Needs

Step 2 - Calculate Embodied Carbon Savings



Step 3 - Add GWP Limits and EPDs to Concrete Specification



SFO BAB CIP Concrete Specification - Draft
2 February 2016

a. Coarse aggregate shall be from specified source for Shrinkage Controlled Concrete. Do not blend pea gravel with shrinkage controlled aggregates.
5. Admixtures: Mid-range, water-reducing admixture at necessary dosage to provide adequate slump and workability at specified water content.
6. ~~Limit total water to 275 lbs maximum.~~
7. Limit water-to-cementitious material ratio to 0.45 by weight. — 0.5
8. shrinkage limit 0.035%
9. Max cement content: 300 pcy OR
9. Max GWP: 300 kg CO2e/m3

F. Mix "B-6000": For formed two-way slabs concrete. — 56?
1. Compressive strength: 6,000 psi at 28 days (ASTM C39).
2. Slump: 6 inches, plus or minus 1-inch tolerance (ASTM C143).
3. Cementitious material: Total cementitious material shall not be less than 550 lbs per cubic yard.
4. Aggregate: Size 67 (3/4-inch) coarse aggregate.
a. Coarse aggregate shall be from specified source for Shrinkage Controlled Concrete. Do not blend pea gravel with shrinkage controlled aggregates.
5. Admixtures: Mid-range, water-reducing admixture at necessary dosage to provide adequate slump and workability at specified water content.
6. ~~Limit total water to 275 lbs maximum.~~
7. Limit water-to-cementitious material ratio to 0.45 by weight. — 0.5
8. Max cement content: 325 pcy OR
8. Max GWP: 325 kg CO2e/m3

G. Mix "C-6000": For walls and columns.

Step 4 - Compare EPDs to Limits in Submittal Review

Step 1 - Determine Project Mix Needs

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"Typical mixes"					
Revit Material Name	CIP 033000 Mix Type	Strength	Elements	Tally take-off basis	reinforcement
Concrete - Mix A Pile Caps	A	4000 psi @ 28d	pile caps	volume	225 pcy
Concrete - Mix A Grade Beams	A	4000 psi @ 28d	grade beams	volume	95 pcy
Concrete - Mix B Fill over Deck	B	4000 psi @ 28d	NWC fill over deck	volume	200 pcy
Concrete - Mix B - 6000	B - 6000	6000 psi @ 28d	2-way suspended slab	area	365 pcy
Concrete - Mix B - 6000 Beams	B - 6000	6000 psi @ 28d	beams	volume	240 pcy
Concrete - Mix C - 6000 Walls	C - 6000	6000 psi @ 28d	walls	volume	250 pcy
Concrete - Mix C - 6000 Columns	C - 6000	6000 psi @ 28d	columns	volume	300 pcy
Tubex Concrete Fill	Tubex 31 63 00	4000 psi @ 28d	tubex fill w/15% FA, w/c 0.4	volume	
Prestressed Piles	PS Piles 31 62 13	7000 psi @ 28d	prestressed conc piles (alt to Tubex)		
not used	D	4000 psi @ 28d	topping slab		
not used	E	4000 psi @ 28d	LWC fill over deck		

cement	course aggregate	sand	water	admixture	perlite	expanded shale	expanded slag	fly ash	glass fibers
90 pcf	95 pcf	100 pcf	62 pcf		30 pcf	45 pcf	58 pcf	50 pcf	168 pcf
% vol	% vol	% vol	% vol	% vol	% vol	% vol	% vol	% vol	% vol

Step 2 - Calculate Embodied Carbon Savings

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San Francisco International Airport
TERMINAL 1 REDEVELOPMENT / BOARDING AREA B

3.3 Building Product and Material Sustainability

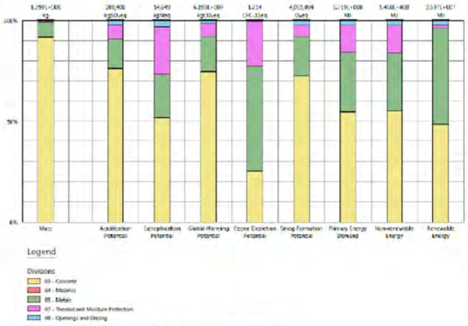
SUSTAINABILITY APPROACH

3.3.1 Whole-Building Lifecycle Analysis

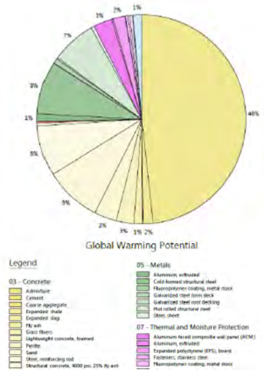
A whole-building Lifecycle Assessment (WBLCA) was performed on the 100% CD model using the Revit model of the building structure and the Tally LCA plug-in to compare two scenarios: a typical or baseline case, and the same model with low-cement concrete mixes.

Per the requirements of the LEEDv4 WBLCA credit, the analysis considered only structure and enclosure materials. For this building, the largest contributor to all impact factors (except ozone depletion) was concrete. And within concrete, cement content is the major driver of impacts. By specifying lower-cement concrete mixes, the entire environmental footprint of the project was substantially reduced. This also allowed for a reasonable definition of a baseline building for the LEED analysis, as the "baseline" concrete mixes were taken from NRMCA (National Ready Mix Concrete Association) standard designs for the required strengths of each mix used on the project.

LEED requires that the project be 10% lower than a baseline building in three impact factors (one of which must be global warming potential) without being more than 5% greater than the baseline building in any impact factor. Our results show that Boarding Area B contributes 12% less to ocean acidification and 11% less to global warming and smog formation than the baseline case, and is 5-6% better in other impact categories as well.



TALLY LCA RESULTS FOR DESIGN CASE, SHOWING BREAKDOWN OF EACH IMPACT FACTOR BY CONSTRUCTION SPECIFICATION DIVISION



Decarbonized Concrete Specifications
Terminal 1 Center & BAB

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1.3 ACTION SUBMITTALS

A. Product Data: Submit product data for each type of product indicated.

B. Sustainable Design Submittals:

1. Sustainability Criteria Worksheet: Submit one worksheet for each component material of the product or assembly used in the installation of Work of this Section.
2. Environmental Product Declaration: An EPD is required, submit in accordance with Section 01 81 13.14 "Sustainability Design Requirements," Article 1.6C.1 "ACTION SUBMITTALS: Sustainable Design Documentation Submittals; MRc2.1 – EPDs."
3. Reports from raw materials suppliers: If available, submit CSR reports from suppliers in accordance with Section 01 81 13.14 "Sustainability Design Requirements," Article 1.6C.2 "ACTION SUBMITTALS: Sustainable Design Documentation Submittals;

O. Environmental Product Declaration: Submit in accordance with Section 01 81 13.14, part 1.6.C.1 LEED Submittals – BPDO – Environmental Product Declarations. All submitted material, of all framing types, must be accompanied by EPDs. Design-Build team will consider the Global Warming Potentials disclosed therein when selecting bids.

HPD, C2C certificate at Bronze level or above, C2C Material Health Certificate, Declare product label, or other acceptable material ingredient inventory in accordance with Section 01 81 13.14 "Sustainability Design Requirements," Article 1.6C.4 "ACTION

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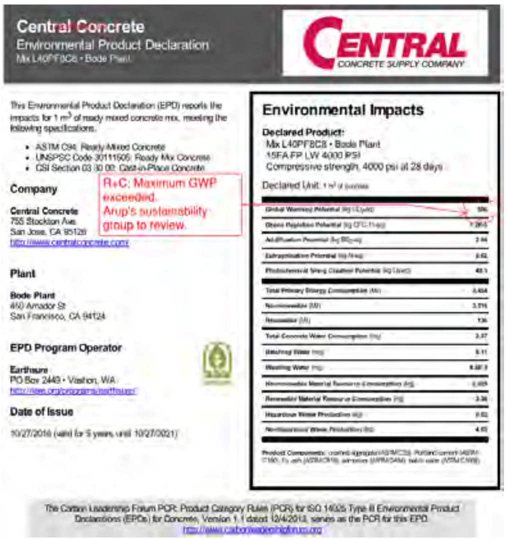
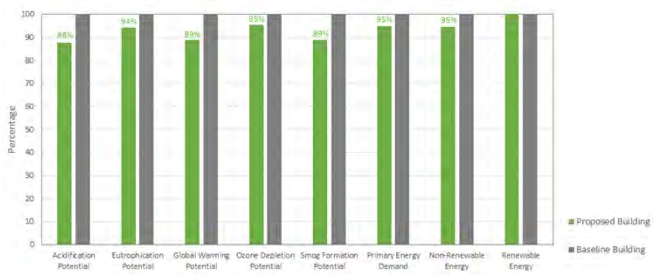
Step 4 - Compare EPDs to Limits in Submittal Review



LEED WBLCA credit check



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SFO Outcomes:
Terminal 1 Boarding Area B

- 8M kgCO2e embodied carbon savings
- 27% reduction within concrete

1800 cars

9000 acres

	Acidification Potential (kgSO2eq)	Eutrophication Potential (kgNeq)	Global Warming Potential (kgCO2eq)	Ozone Depletion Potential (CFC-11eq)	Smog Formation Potential (kgO3eq)	Primary Energy Demand (MJ)	Non-renewable Energy Demand (MJ)	Renewable Energy Demand (MJ)	Mass (kg)
Baseline (typical cement mix)	320,092	15,564	69,647,095	1.27	4,555,735	602,722,891	576,889,241	25,928,986	139,714,746
As-Designed (low-GWP concrete mixes)	280,400	14,649	61,930,455	1.21	4,051,094	571,850,604	545,971,939	25,971,372	139,887,038
Design compared to baseline	-12%	-6%	-11%	-5%	-11%	-5%	-5%	0%	0%

TALLY LCA RESULTS COMPARISON FOR BASELINE V. DESIGN CASE

10% reduction in GWP through structure and envelope strategies helped secure the points needed to tip the project from LEED Gold to ***LEED Platinum***

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SFO Outcomes: Terminal 1 Center

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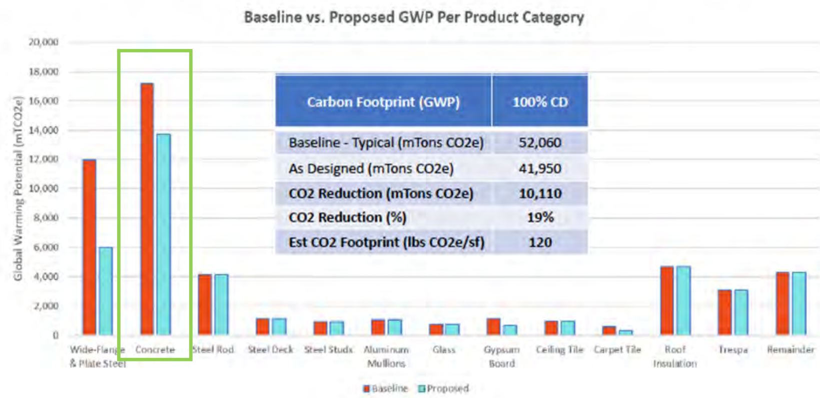
SFO T1's Embodied Footprint @ Design



Carbon Footprint (GWP)	100% CD
Baseline - Typical (mTons CO2e)	52,060
As Designed (mTons CO2e)	41,950
CO2 Reduction (mTons CO2e)	10,110
CO2 Reduction (%)	19%
Est CO2 Footprint (lbs CO2e/sf)	120

Source: Urban Fabrik

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SFO Pilot Project: Test Pour of Blue Planet™ Aggregate

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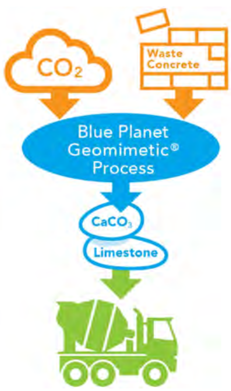
- Interim Boarding Area B
- Aggregate = Blue Planet Pumice + CO_2



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Bay Area Low Carbon Concrete Code

- Funded by BAAQMD's 2018 Climate Protection Grant Program under "Fostering Innovative Strategies with long-term impacts in reducing GHG emissions."
- A first-of-its-kind effort to address embodied emissions in an area of local government control.
- Partnership with local government, engineers, and academia, as well as a robust stakeholder group which shaped the standards.

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Cement or Embodied Carbon (GWP) Limits

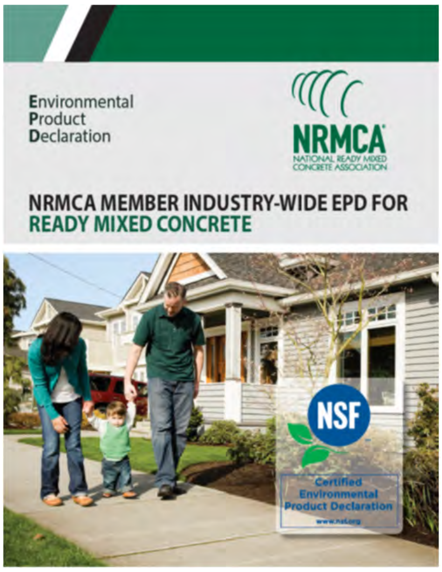
Table 19.07.050 Cement and Embodied Carbon Limit Pathways

	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 CO2e/m³, 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.

19.07.050.1 Allowable Increases

(1) *Cement and Embodied Carbon Limit Allowances.* Cement or Embodied Carbon limits shown in Table 19.07.050 can be increased by 30% for concretes demonstrated to the Building Official as requiring high early strength. Such concretes could include, but are not limited to, precast, prestressed concrete; beams and slabs above grade; and shotcrete



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SEAONC Concrete Mix Design Collection

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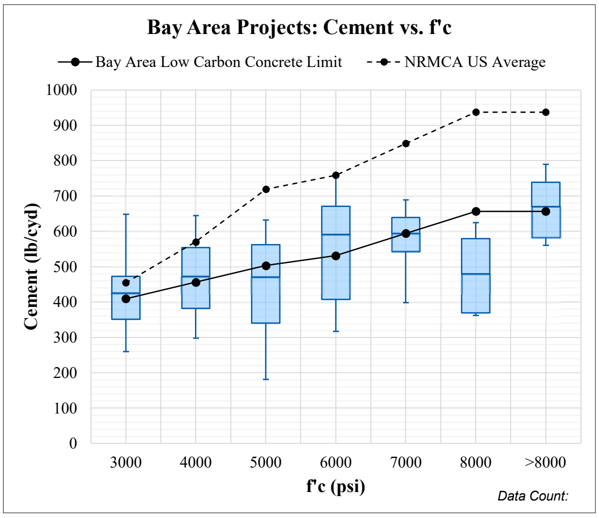

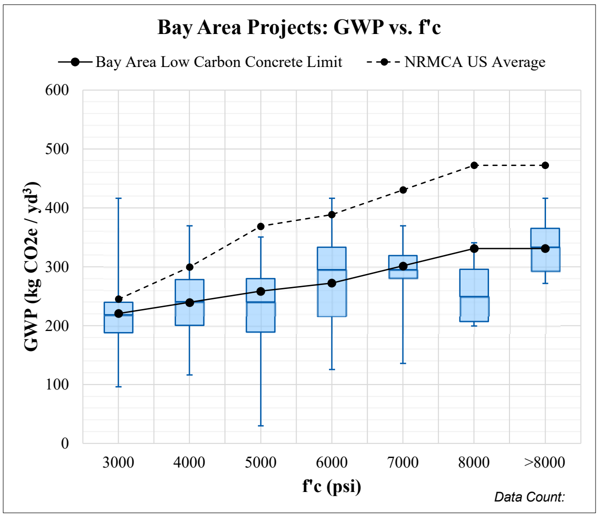

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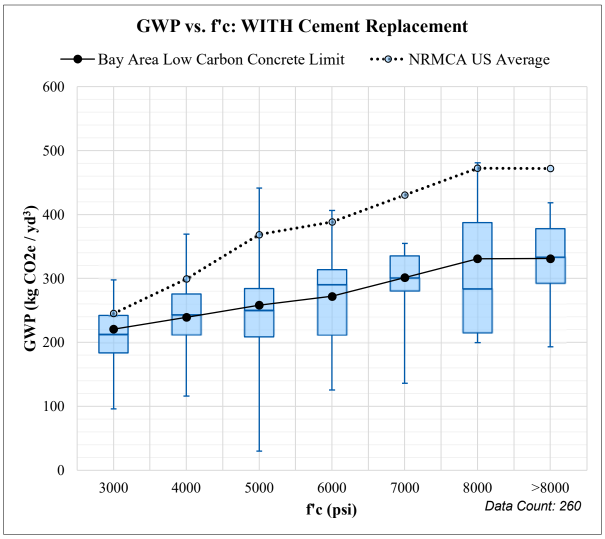
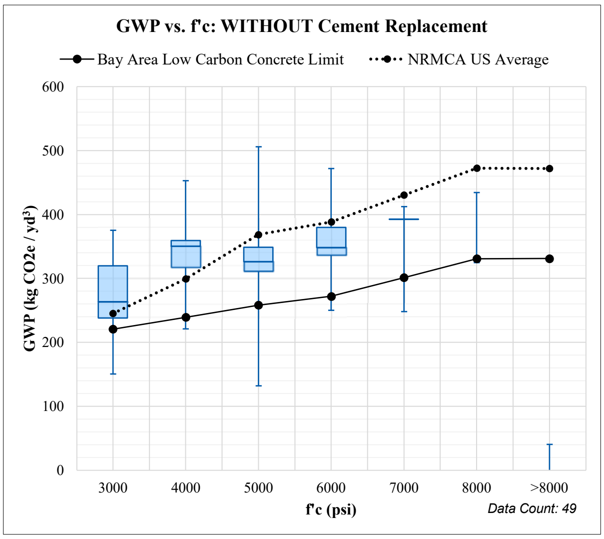
SEAONC Concrete Mix Design Collection





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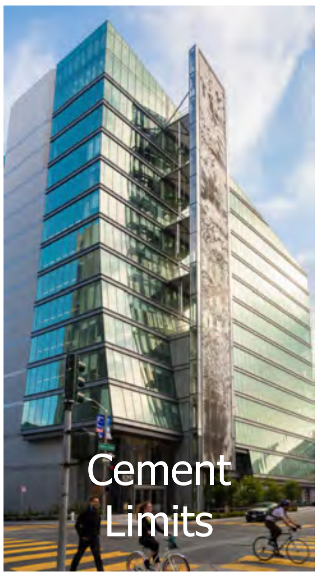
Project Precedents



From left:
David Brower Center
SFO Terminal 1
SF PUC / 555 Golden Gate
Confidential Office by Arup

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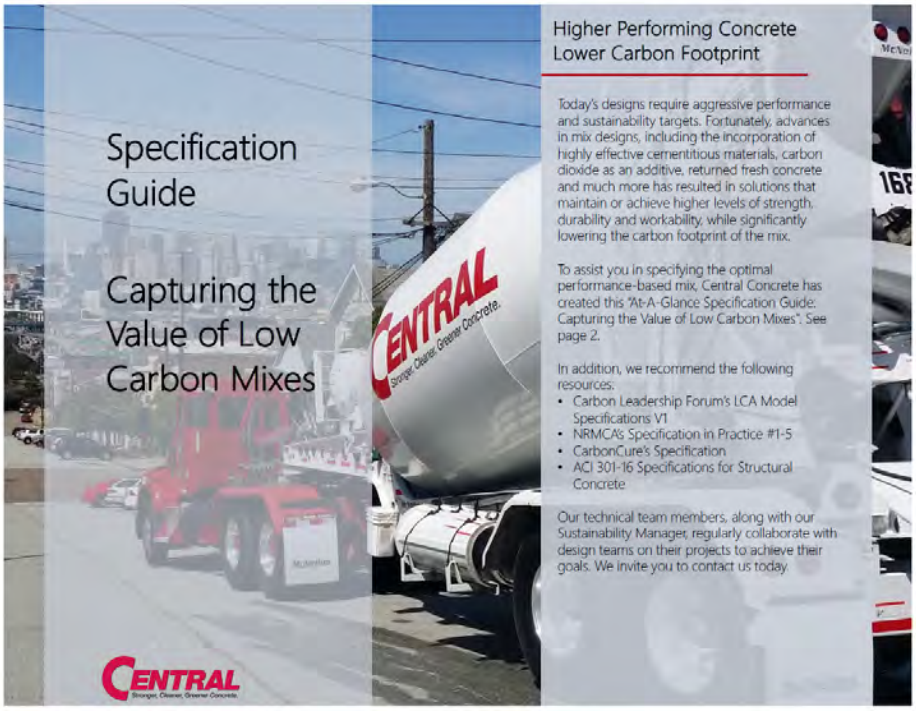

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Reflected in the sample commercial spec clauses

https://www.marincounty.org/depts/cd/divisions/sustainability/low-carbon-concrete-project

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Bay Area Low Carbon Concrete Code

- Model code language for adoption by local governments
  - Low embodied-carbon concrete specifications for residential and non-residential applications
  - **Adopted unanimously by County of Marin on November 19, 2019**
- Opportunity for these standards to be adopted across Bay Area jurisdictions; and for the framework to be replicated beyond our region.

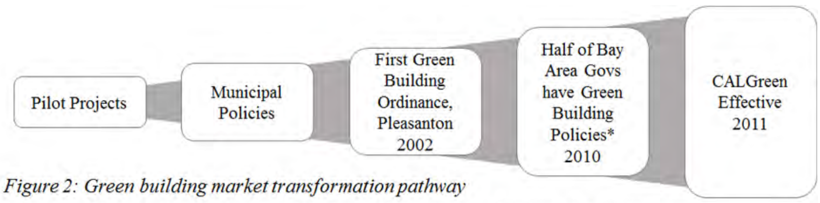

Figure 2: Green building market transformation pathway

* Bay Area Regional Collaborative Bay Area Green Building Policy Assessment Aug. 20, 2010

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Timeline

2012	LEEDv4 released	2019	Opening of SFO Harvey Milk Terminal 1 Phase 1
2013	SFO ZNE Commitment and adoption of LEEDv4 in RFP for T1 Redevelopment	2020	Marin Co. adoption of Low Carbon Concrete Code
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2017	Specifications issued for SFO T1 Buy Clean CA	2024	Concrete Innovation Award LCC update in SFO SPDC Guidelines
2018	Bay Area Low Carbon Concrete code development SEAONC Concrete Mix Design Analysis		

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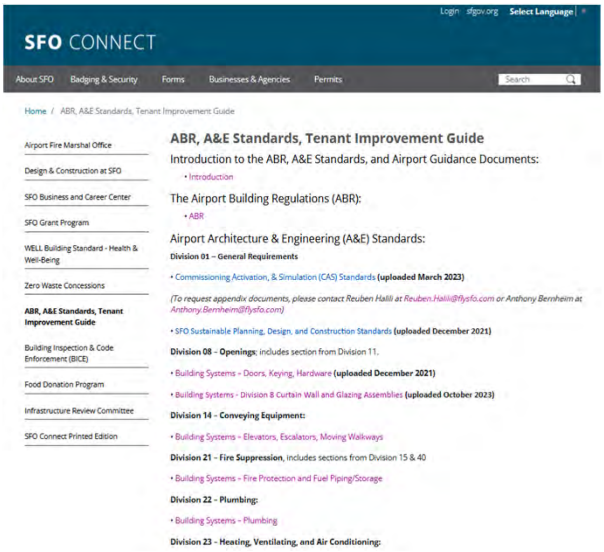
Codes, Standards, & Guidelines:
SFO Sustainable Planning, Design, & Construction Standards



- SFO Sustainable Planning, Design, & Construction Standards, Chapter 6: Materials & Resources
- Decarbonized Concrete Guidance
- CarbonStar signals the goal of carbon negative concrete
- Direct projects to use EC3 for EPD documentation

https://www.sfoconnect.com/architectural-and-engineering-ae-standards

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Codes, Standards, & Guidelines:
Comparison of GWP Limits

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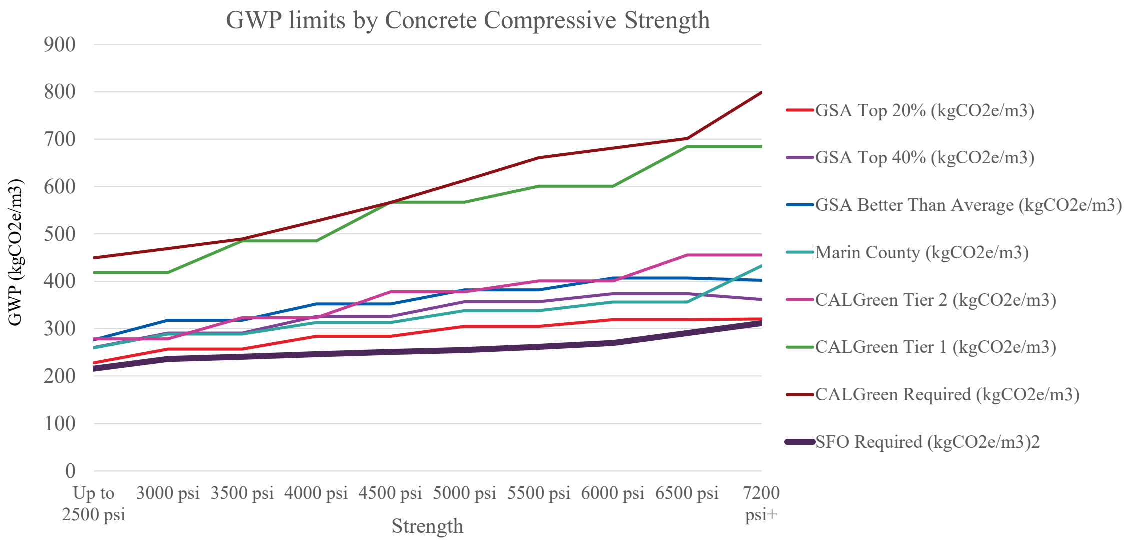

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Codes, Standards, & Guidelines:
SFO Sustainable Planning, Design, & Construction Standards

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Required

Ensure that all concrete mixes used adhere to Table X.X "GWP Limits per Concrete Strength Class - Required". The GWP of each concrete mix should come from third-party verified concrete EPDs following the US Concrete PCR v2.3 (NSF/ASTM 1112-19 with 2024 deviation & 2024 extension) or later. Utilize the EC3 tool to track EPDs for the concrete products used for the project.

For all concrete mixtures that use carbon-sequestering technology to meet the limits below, meet the Carbon Sequestering Technologies Disclosure Requirements detailed in section below.

Minimum specified compressive strength f'_c, psi	Embodied Carbon Limits (metric) kg CO_2e/m^3, per Type III EPD	Embodied Carbon Limits (imperial) lb CO_2e/yd^3 per Type III EPD
up to 2500	216	364
3000	236	398
4000	246	414
5000	255	431
6000	270	455
7000	291	491
8000+	312	527
LW 3000	472	796
LW 4000	492	829
LW 5000	511	861

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Codes, Standards, & Guidelines:
SFO Sustainable Planning, Design, & Construction Standards

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Reach

Ensure that **at least 5% of concrete** used in the project, by volume, adheres to Table X.X "GWP Limits per Concrete Strength Class – Reach". The GWP of each concrete mix should come from third-party verified concrete EPDs following the US Concrete PCR v2.3 (NSF/ASTM 1112-19 with 2024 deviation & 2024 extension) or later. Utilize the EC3 tool to track EPDs for the concrete products used for the project.

For all concrete mixtures that use carbon-sequestering technology to meet the limits below, meet the Carbon Sequestering Technologies Disclosure Requirements detailed in section below.

Minimum specified compressive strength f'c, psi	Embodied Carbon Limits kg CO_2e/m^3, per Type III EPD	Embodied Carbon Limits lb CO_2e/yd^3, per Type III EPD
up to 2500	0 to 70	0 to 118
3000	0 to 78	0 to 131
4000	0 to 96	0 to 162
5000	0 to 117	0 to 197
6000	0 to 124	0 to 209
7000+	0 to 144	0 to 243
LW 3000	0 to 156	0 to 262
LW 4000	0 to 192	0 to 324
LW 5000	0 to 234	0 to 394

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Codes, Standards, & Guidelines:
SFO Sustainable Planning, Design, & Construction Standards

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Regenerative

Using a volume weighted average approach, achieve a total average GWP of 0 kg CO_2e/m^3 or 0 lb CO_2e/yd^3 or less across the entire project, calculated according to Equation X.X. The GWP of each concrete mix should come from third-party verified concrete EPDs following the US Concrete PCR v2.3 (NSF/ASTM 1112-19 with 2024 deviation & 2024 extension) or later. Utilize the EC3 tool to track EPDs for the concrete products used for the project.

For all concrete mixtures that use carbon-sequestering technology to meet the limits below, meet the Carbon Sequestering Technologies Disclosure Requirements detailed in section below.

Equation X.X

$$\frac{\Sigma\, GWP_n \cdot V_n}{V_{tot}} \leq 0$$

Where

- *n:* The total number of concrete mixtures for the project
- GWP_n: The global warming potential for mixture $_n$ as per Type III EPD
- V_n: The volume of mixture $_n$ concrete to be placed, m^3 or yd^3
- V_{tot}: The total volume of all concrete mixtures to be placed, m^3 or yd^3

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Codes, Standards, & Guidelines: CarbonStar®

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- SFO involved in development of CarbonStar
- Simple and easy-to-compare quantification of concrete GWP for concrete mixes using carbon-sequestering technology in its constituent materials
- CarbonStar® = Embodied CO_2e – Sequestered CO_2e
- Modeled after ENERGY STAR®
- Complements concrete EPDs and PCRs, resulting equation can be provided in the additional information section of EPDs

www.carbonstar.org

"The CarbonStar Standard and Calculator was designed to guide building professionals in the specification and use of low embodied and sequestered carbon concrete products.

Building professionals can use CarbonStar to facilitate procurement of environmentally preferable concrete using a standardized approach to carbon accounting thereby creating efficiencies during the building process."

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Low-Carbon Concrete Products: Blue Planet™ Aggregate

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- Blue Planet synthetic limestone aggregate can theoretically offset all the emissions from the cement in the concrete, making the mix carbon negative.
- The calcium source, referred to as geomass, can be a range of materials:
  - Demolished/Returned Concrete
  - Cement Kiln Dust
  - Steel Slag
  - Fly Ash / APCr
  - Bauxite Residue
  - Silicate Rocks

Embodied Carbon of Blue Planet concrete calculated using CarbonStar rating system

Carbon emitted

Mix details		Mass (lb/yd³)	Carbon emitted
Cement	Portland Cement	600	624
Water	Municipal Water	300	0.06
A3 phase (production of concrete at ready-mix plant)	Grid Electricity	-	1.8

Carbon sequestered

Mix details		Mass (lb/yd3)	Carbon sequestered
Coarse aggregate	Blue Planet CaCO³	1500	-600
Fine aggregate	Blue Planet CaCO³	1300	-520
CarbonStar® rating (lb CO_2/yd³ concrete)			-494

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Low-Carbon Concrete Products: Others

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cocoon

- Supplementary Cementitious Material (SCM) from materials like steel slag, cement kiln dust, biomass ash, fly ash, mine tailings, and demolition waste.
- Permanently stores CO2.

ECONCRETE

- Concrete admix for use in marine environments.
- Encourages growth of marine organisms which act as biological glue.

carbon upcycling

- SCMs from over 30 different feedstocks so far, including fly ash, steel slags, glass, biomass, volcanic rocks, natural pozzolans, metal mine tailings, aggregate fines, silicates and clays

Think pozzotive

- Replaces up to 50% of cement in concrete.
- Ground glass filler made from recycled glass.

BRIMSTONE

- Portland cement made with calcium silicate rock instead of limestone.
- Chemically and physically identical to conventional Portland cement.
- Produces both Portland cement and supplementary cementitious materials (SCM) from the same process.
- Process produces magnesium which sequesters carbon.

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Timeline

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2024	Concrete Innovation Award LCC update in SFO SPDC Guidelines

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FY0

Decarbonized Concrete Specifications
Bus Maintenance Facility (SFO)

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Location	Strength (psi)	Maximum GWP Limit ($kgCO_2e/m^3$)	Maximum Reach GWP Limit ($kgCO_2e/m^3$)	Maximum Regenerate GWP Limit ($kgCO_2e/m^3$)	Concrete Quantity (CY)	Maximum Allowable Carbon (kg CO_2e) = CY x GWP x 0.765m³/cy	Reach Target Maximum Allowable Carbon (kg CO_2e) = CY x GWP x 0.765m³/cy	Regenerate Target Maximum Allowable Carbon (kg CO_2e) = CY x GWP x 0.765m³/cy
Grade beams/Structural Slabs/Mat slabs	5,000	Max GWP limit 300	Reach GWP limit 270	Regenerate GWP limit 2[illegible]0 kg/m3				
Walls / Curbs / Housekeeping Pads/ Reinforced Concrete Bus Pads / Drainage Structures / Concrete Encasements / Gutters / Other Minor Structures	4,000	Max GWP limit 275	Reach GWP limit 248	Regenerate GWP limit 1[illegible]3 kg/m3				
				Maximum Total Concrete Carbon Targets (sum of each column), $kgCO_2e$:				

Bidder fills out blank spaces.

Location	Strength (psi)	Concrete Mix ID	Concrete Quantity (CY)	Mix GWP ($kgCO_2e/m^3$)	Concrete Carbon (kg CO_2e) = CY x GWP x 0.765m³/cy
Same as Table 1	Same as Table 1	Contractor to fill out	Contractor to fill out	Contractor to fill out from concrete supplier's EPD	Contractor to calculate using equation above
		Submitted Total Concrete Carbon (sum of column), $kgCO_2e$:			

Which total concrete carbon target from Table 1 is achieved by this total concrete carbon?

☐ Maximum ☐ Reach ☐ Regenerate

SFO

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Codes, Standards, & Guidelines:
Building Transparency (EC3) and SFO Template

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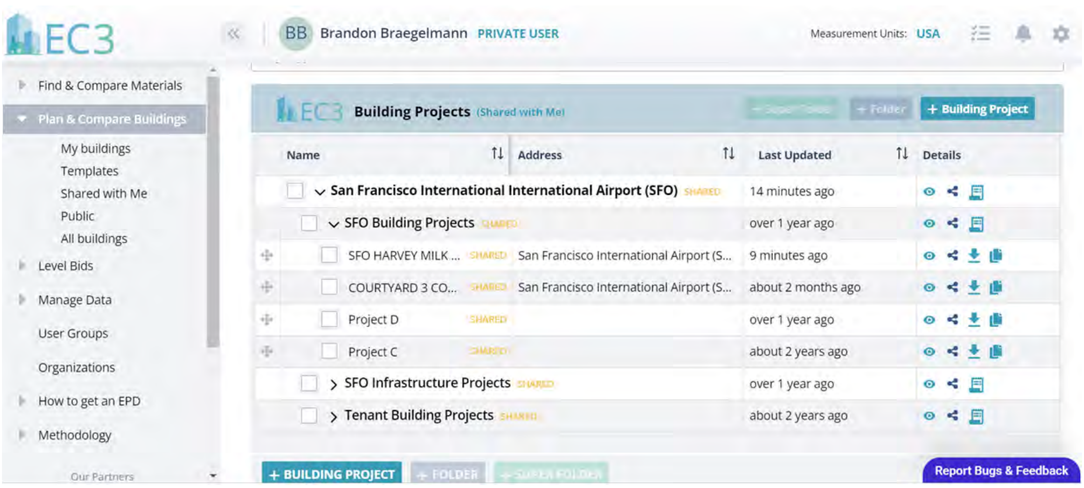

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Slide 37

FY0 Ask Christine about Bus Maint year and process
Frances Yang, 2024-08-18T20:57:56.969

Low-Carbon Concrete Products: Supplementary Cementitious Materials (SCMs)

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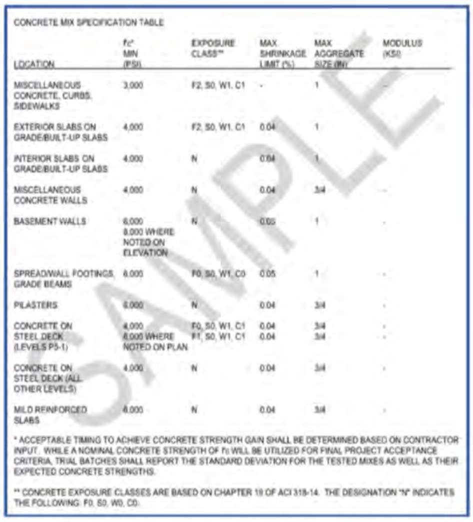
Don't Stifle Innovation – Prioritize Performance

Do you really need to specify:

- Slump (contractor means and methods)
- Minimum cement and max w/c beyond req'd in ACI 318 Chapter 9 for durability
- Maximum % Allowable Cementitious Alternatives (SFO never F3)

2



CONCRETE MIX SPECIFICATION TABLE

LOCATION	f'c* MIN (PSI)	EXPOSURE CLASS**	MAX SHRINKAGE LIMIT (%)	MAX AGGREGATE SIZE (IN)	MODULUS (KSI)
MISCELLANEOUS CONCRETE, CURBS, SIDEWALKS	3,000	F2, S0, W1, C1	-	1	-
EXTERIOR SLABS ON GRADE/BUILT-UP SLABS	4,000	F2, S0, W1, C1	0.04	1	
INTERIOR SLABS ON GRADE/BUILT-UP SLABS	4,000	N	0.04	1	
MISCELLANEOUS CONCRETE WALLS	4,000	N	0.04	3/4	-
BASEMENT WALLS	6,000 8,000 WHERE NOTED ON ELEVATION	N	0.05	1	-
SPREAD/WALL FOOTINGS, GRADE BEAMS	6,000	F0, S0, W1, C0	0.05	1	-
PILASTERS	6,000	N	0.04	3/4	-
CONCRETE ON STEEL DECK (LEVELS P5-1)	4,000 6,000 WHERE NOTED ON PLAN	F0, S0, W1, C1 F1, S0, W1, C1	0.04 0.04	3/4 3/4	- -
CONCRETE ON STEEL DECK (ALL OTHER LEVELS)	4,000	N	0.04	3/4	-
MILD REINFORCED SLABS	6,000	N	0.04	3/4	-

* ACCEPTABLE TIMING TO ACHIEVE CONCRETE STRENGTH GAIN SHALL BE DETERMINED BASED ON CONTRACTOR INPUT. WHILE A NOMINAL CONCRETE STRENGTH OF f'c WILL BE UTILIZED FOR FINAL PROJECT ACCEPTANCE CRITERIA, TRIAL BATCHES SHALL REPORT THE STANDARD DEVIATION FOR THE TESTED MIXES AS WELL AS THEIR EXPECTED CONCRETE STRENGTHS.

** CONCRETE EXPOSURE CLASSES ARE BASED ON CHAPTER 19 OF ACI 318-14. THE DESIGNATION "N" INDICATES THE FOLLOWING: F0, S0, W0, C0.

SAMPLE

Figure 4.1.1 – Example Concrete Mix Design Table from General Notes (Source: MKA)

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SFO Keys to Success

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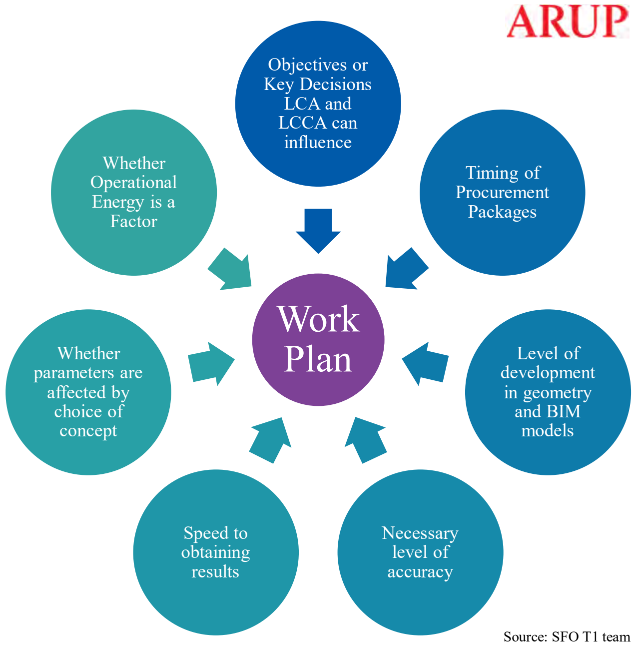
From a consultant's perspective

- Clear and consistent ambitions upfront
- Process for vetting big decisions
- Support from ZERO Team
- Progressive Design-Build contract structure
- Big Room mentality
- Alignment with best practice
- Two-way education



Source: SFO T1 team

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