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Action Steps to Low-Carbon Concrete—

Cementing Low Carbon Construction

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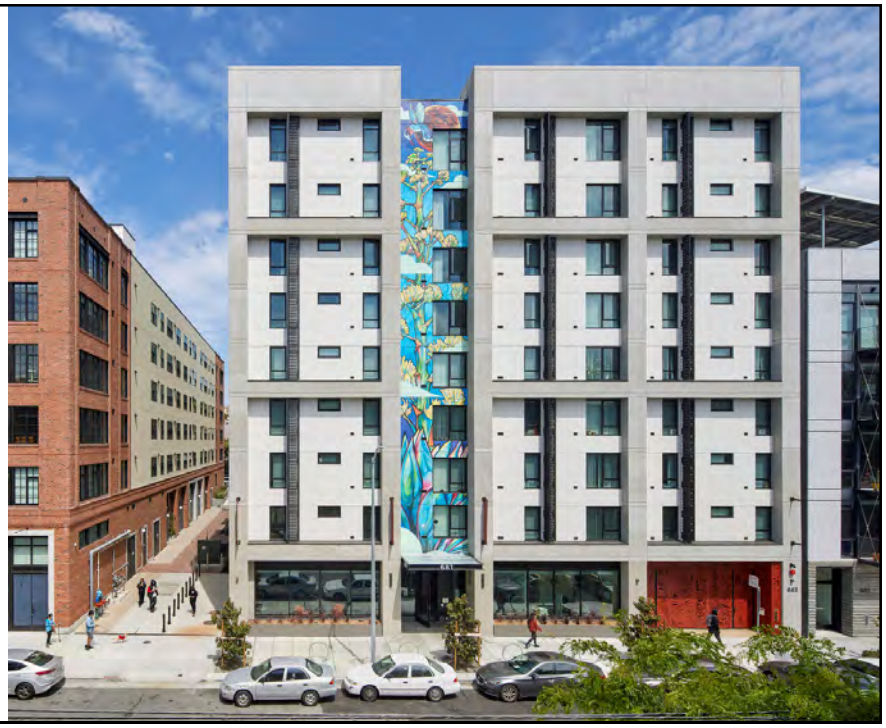
NRMCA Concrete Innovations
Session 25

October 16th, 2024



8 AIA COTE TOP TEN GREEN AWARDS

10+ NET ZERO ENERGY CHALLENGE TARGET

10 DISTRICT PROJECTS WITH HEALTH EQUITY ASSESSMENTS

5 FITWEL + WELL REGISTERED PROJECTS

2 ECODISTRICTS REGISTERED PROJECTS

150+ GREEN STORMWATER PROJECTS

100+ LEED CERTIFIED BUILDINGS

15+ PROJECTS WITH GREEN DISTRICT SCALE SYSTEMS

500+ SUSTAINABLE DESIGN PRESENTATIONS

CARBON NEUTRAL OPERATIONS SINCE 2004

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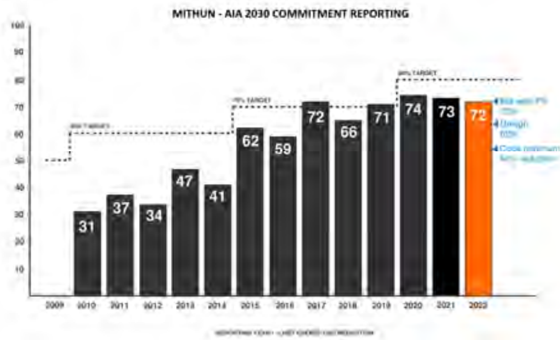
Design for Decarbonization

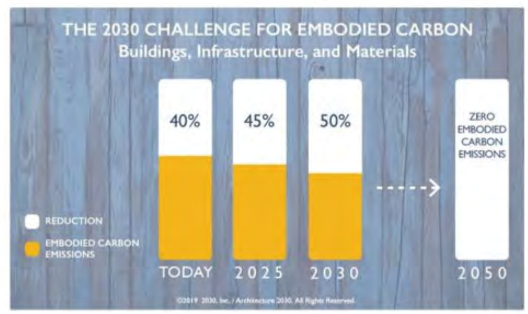
Mithun is a signatory to Architecture 2030, formally committing to substantial reductions of operational and embodied carbon in every building we design.

- **Net Zero Energy-** current target is to achieve an 80% reduction of Site EUI compared to baseline
- **Low Embodied Carbon-** the 2030 commitment recently began requiring architecture firms to track and report embodied carbon for new buildings.

architecture 2030

AIA 2030 COMMITMENT





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New municipal codes regulating global warming potential in concrete are in development.

Like other sustainability metrics, the architect will need to navigate which path makes most sense for the project, communicate these requirements with the owner, and work with engineers and contractors to achieve compliance.

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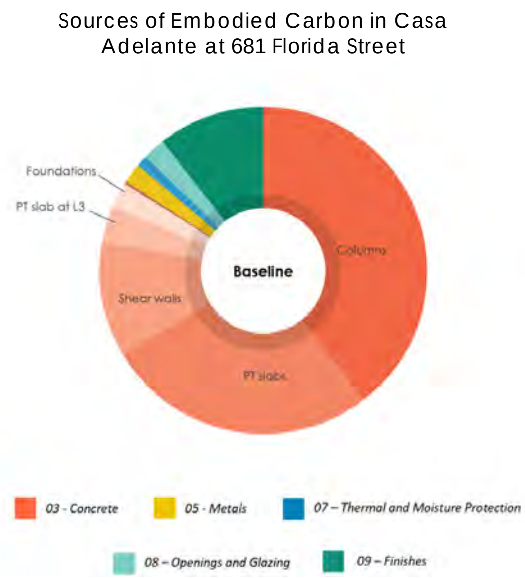
Why concrete?



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A Pilot Project for a Low-Carbon Concrete Model Code

- Funded by BAAQMD's 2018 Climate Protection Grant Program.
- 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.

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.

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

COUNTY OF MARIN   STOPWASTE   ARUP   CLF Carbon Leadership Forum   EBNet Ecological Building Network the art and science of building well

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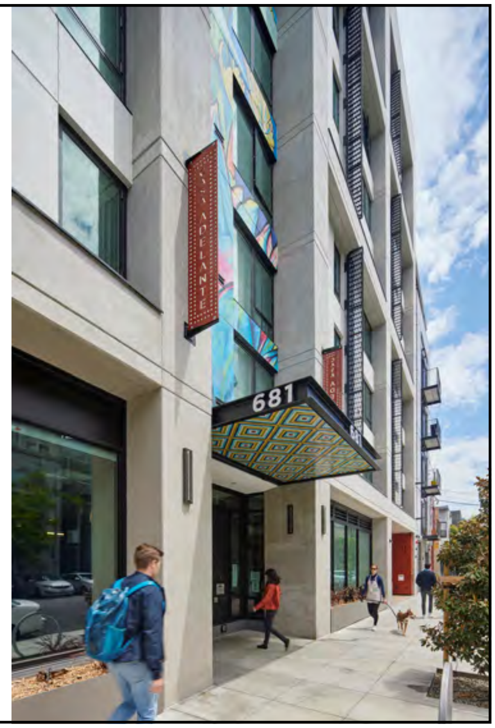
A good candidate for testing the Low Carbon Concrete Code.

- 130 units of affordable family housing with community commercial, all-electric
- Multiple federal, state, local, and private funding sources (MOHCD, LIHTC, CDLAC)
- All-concrete structure, exposed throughout building at interior and exterior
- Targeting **ILFI Zero Carbon Certification** through the Affordable Housing Pilot Project Program (Cohort #4)
- Also targeting GreenPoint Rated Platinum and Fitwel Certification



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The building and the team made this project a good candidate to pilot the Low Carbon Concrete Code...

ownership team with big goals

tndc HOMES. HEALTH. VOICE. — meda Mission Economic Development Agency

TNDC Sustainability Manager proposed this project to be part of the pilot program

contractor team willing to help

CAHILL — GUZMAN CONSTRUCTION GROUP

Facilitating conversations between design team & subcontractors/suppliers before Bid/GMP

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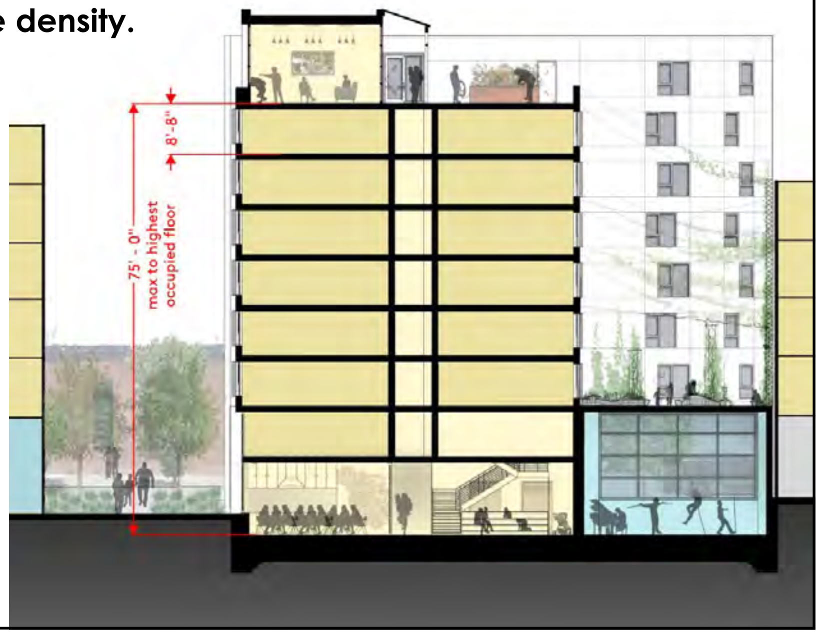
Concrete remains an invaluable tool for achieving cost-effective density.

- 8" post-tensioned slabs, achieving necessary acoustic & fire separation
- Able to fit 9 stories within the 75' high-rise height limit
- Durable material that property owners can trust
- Exposed floors, ceilings, walls, and columns reduces total materials



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Conventional process of concrete specification is linear
and provides little room for analysis of embodied carbon.

primary structure selected ▶ **structural design & permitting** ▶ **project is bid** ▶ **construction**

1. **primary structure selected** — Developer & design team decide on building type (ideally, with input from contractor).

   "concrete"

2. **structural design & permitting** — Usually, there is minimal scrutiny of structural specifications, especially for hidden or non-exposed structure (such as large concrete foundations or structural decks).

   "slabs, walls, columns..."

3. **project is bid** — Concrete subcontractor & supplier price using strength requirements. Whether competitive or negotiated bidding, there is little room for nuanced concrete mix discussions.

   "slab type A, B, C ... wall types A, B, C ..."

4. **construction** — Mix designs are reviewed for conformance to strength requirements. GWP is often not considered. Lower GWP alternates are rarely provided, because they are more work with no guarantee of approval.

   "slab type A mix 1 ... wall type B mix 2.C ..." etc etc etc...

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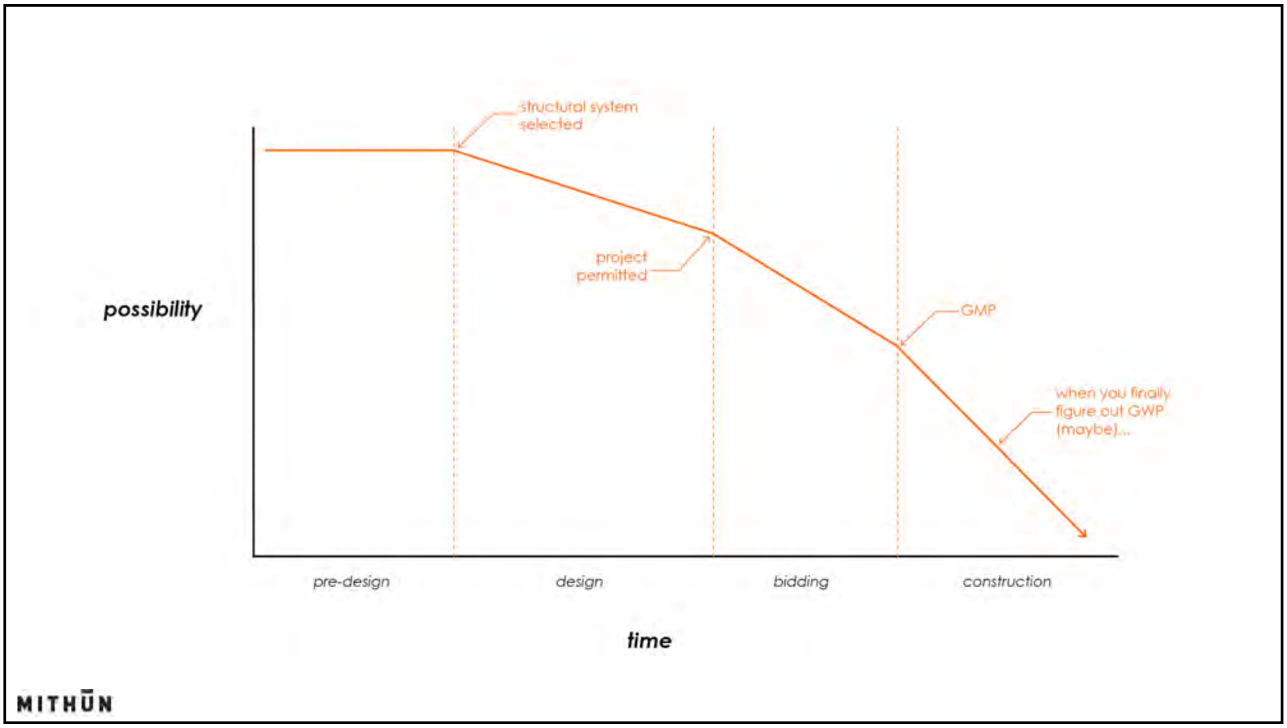
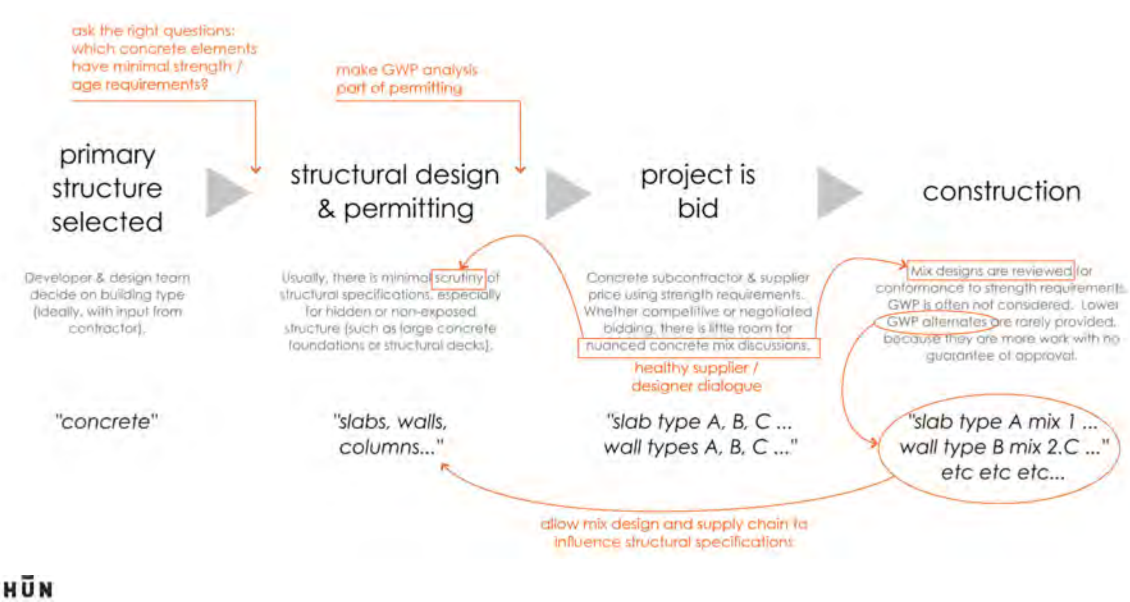
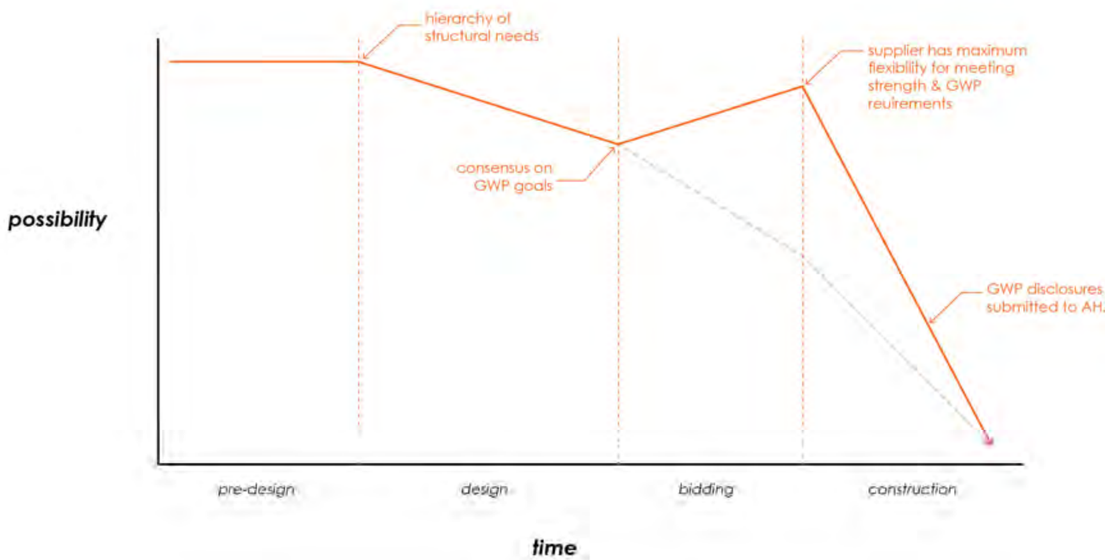


How can we subvert the conventional process?





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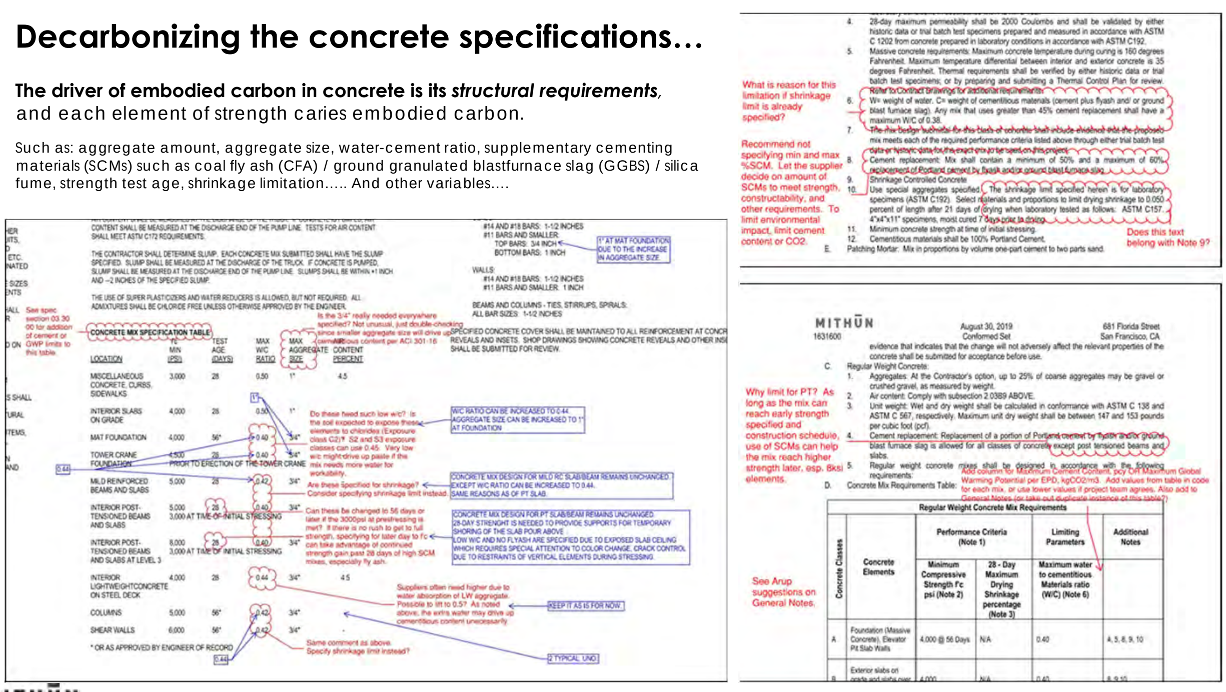
Decarbonizing the concrete specifications…

The driver of embodied carbon in concrete is its *structural requirements*, and each element of strength caries embodied carbon.

Such as: aggregate amount, aggregate size, water-cement ratio, supplementary cementing materials (SCMs) such as coal fly ash (CFA) / ground granulated blastfurnace slag (GGBS) / silica fume, strength test age, shrinkage limitation….. And other variables….



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681 Florida - San Francisco, CA

Submitted Concrete per Specification: Total GWP is 19,890 kg CO_2eq higher than GWP Limit per Code

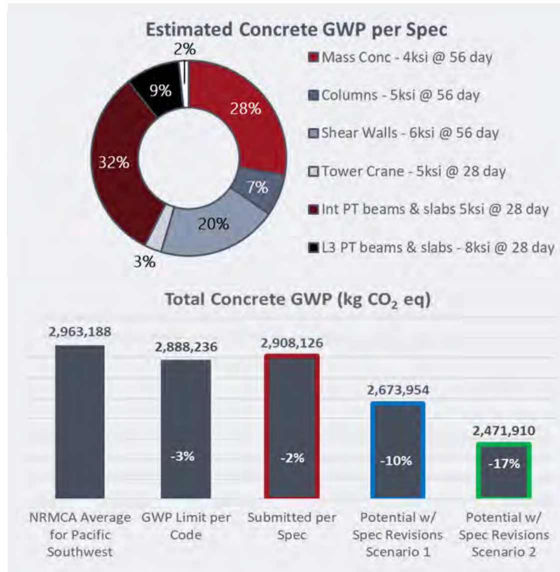
- **Mass Concrete 0.40 w/c – 40% SCM Replacement**
- **Columns 0.42 w/c – 25% SCM Replacement**
- Shear Walls 0.42 w/c – 40% SCM Replacement
- **Tower Crane 0.40 w/c – 30% SCM Replacement**
- **PT Beams & Slabs 5ksi 0.40 w/c – 30% SCM Replacement**
- PT Beams & Slabs 8ksi 0.40 w/c – 0% SCM Replacement

Scenario 1: Total GWP is 214,282 kg CO_2eq lower than GWP Limit per Code

- ***Mass Concrete* 0.45 w/c – 50% SCM Replacement**
- ***Columns* 0.45 w/c – 50% SCM Replacement**
- Shear Walls 0.42 w/c – 40% SCM Replacement
- ***Tower Crane 0.44 w/c – 30% SCM Replacement***
- ***PT Beams & Slabs 5ksi* 0.42 w/c – 30% SCM Replacement**
- PT Beams & Slabs 8ksi 0.40 w/c – 30% SCM Replacement

Scenario 2: Total GWP is 416,326 kg CO_2eq lower than GWP Limit per Code

- ***Mass Concrete* 0.45 w/c – 70% SCM Replacement**
- ***Columns* 0.45 w/c – 70% SCM Replacement**
- Shear Walls 0.42 w/c – 40% SCM Replacement
- *Tower Crane 0.44 w/c – 30% SCM Replacement*
- ***PT Beams & Slabs 5ksi* 0.42 w/c – 30% SCM Replacement**
- PT Beams & Slabs 8ksi 0.40 w/c – 30% SCM Replacement

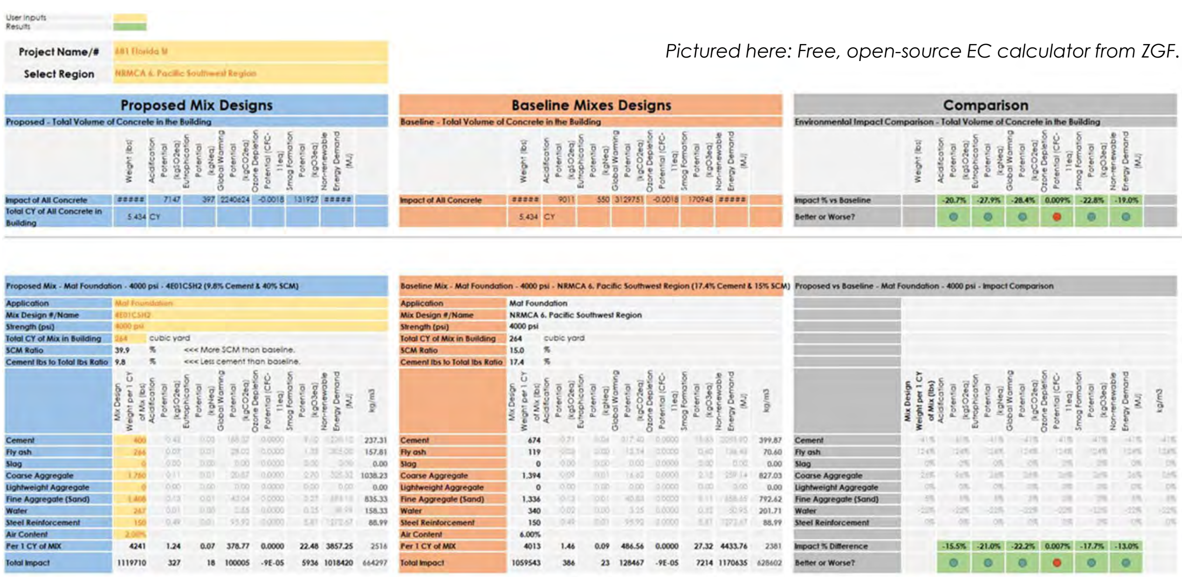


CENTRAL CONCRETE SUPPLY COMPANY

US CONCRETE

After inputting values for each concrete mix into EC calculators...

Pictured here: Free, open-source EC calculator from ZGF.



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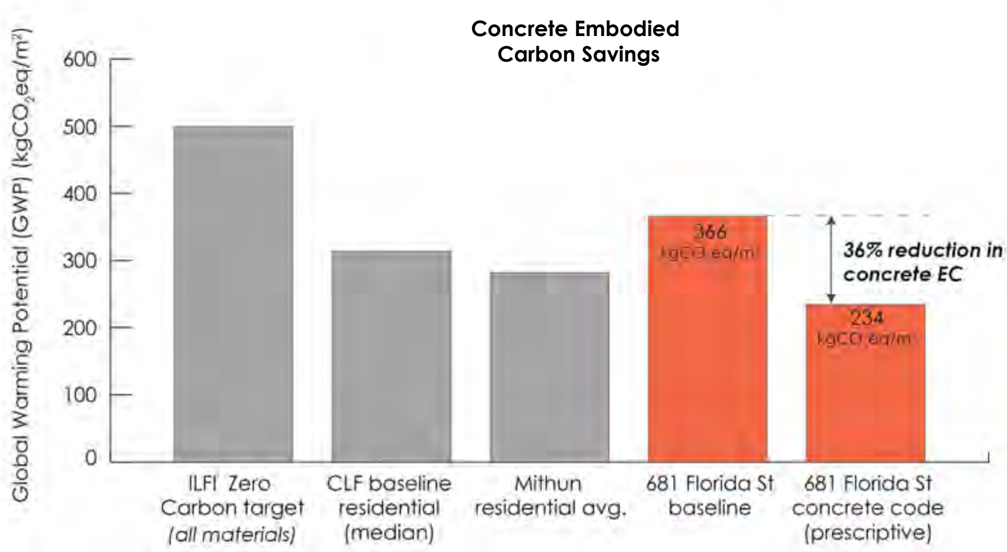
...the model code revisions achieved a 36% reduction
in concrete embodied carbon over originally specified mix



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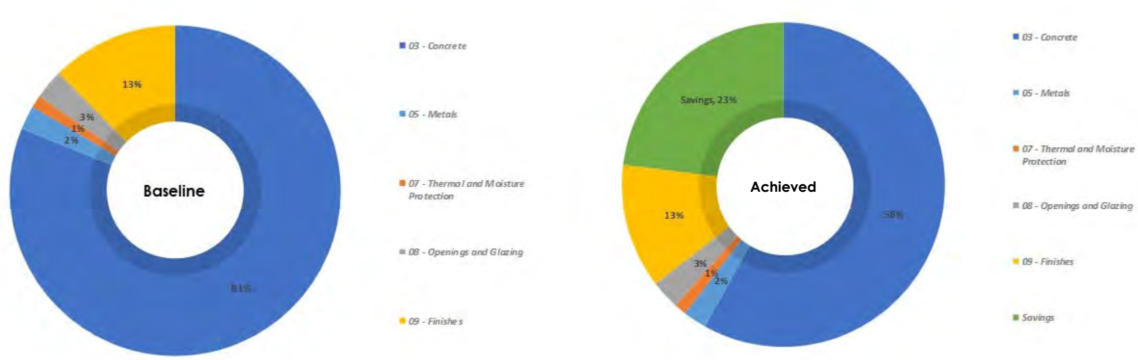
...and a 23% reduction in total embodied carbon
across the whole project (including all other materials).



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Changing concrete specification to remove cement minimums yielded a cost savings.

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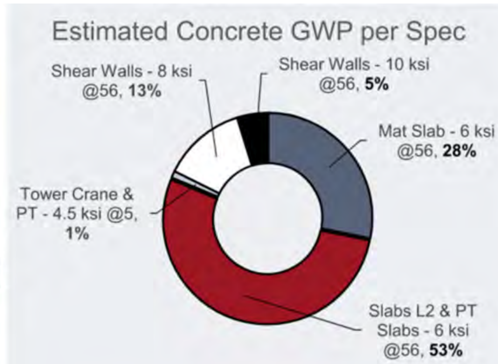
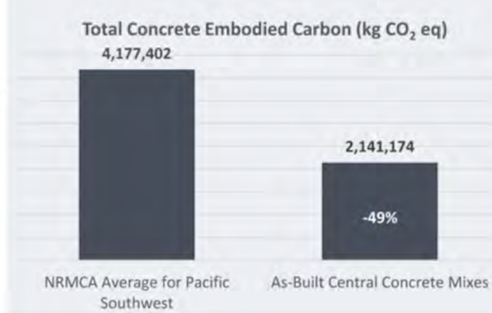
Balboa Upper Yard
Affordable Housing

Concrete Quantity (excludes lightweight): 11,741 cy

As Built (San Francisco Plant):
All include CarbonCure recycled CO_2

- Mat Slab (6 ksi @56) – 4,451 cy
    - 70% SCM, GWP = 175
- L2 Slab & PT Slabs (4.5 ksi @3 / 6 ksi @56) – 4,825 cy
    - 70% SCM, GWP = 304
- Tower Crane (4.5 ksi @5 / 6ksi @56) – 158 cy
    - 70% SCM, GWP = 192
- Shear Wall (8 ksi @56) – 1,564 cy
    - 70% SCM, GWP = 230
- Shear Wall Level 1 (10 ksi @56) – 533 cy
    - 70% SCM, GWP = 248





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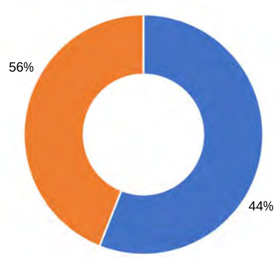
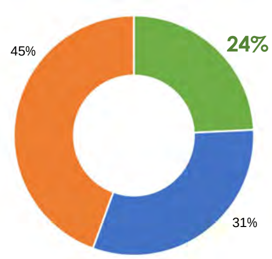
Embodied carbon savings is even more significant on a podium building.

Assuming 4 stories of wood over 1 story of concrete...

- GWP of Concrete
- GWP of all other materials
- GWP Savings



270.2 kgCO2e/m²
"business as usual" concrete



205.1 kgCO2e/m²
same concrete mixes as 681 Florida St

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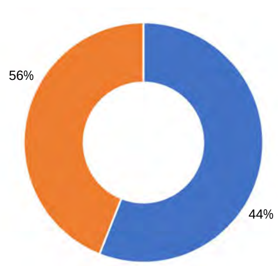
Assuming the Mithun 2022 average for GWP of wood construction for multi-family housing, 120.2 kgCO2/m²

Embodied carbon savings is even more significant on a podium building.

Assuming 4 stories of wood over 1 story of concrete...

- GWP of concrete
- GWP of all other materials
- GWP savings

Throw in a 120 car parking garage...



270.2 kgCO2e/m²
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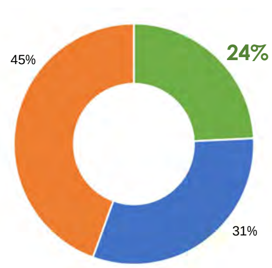
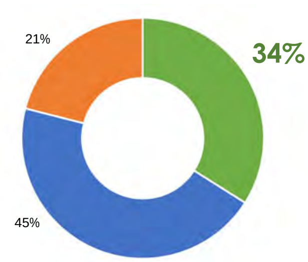


205.1 kgCO2e/m²
same concrete mixes as 681 Florida St



saves 194.4 kgCO2e/m²
same concrete mixes as 681 Florida St

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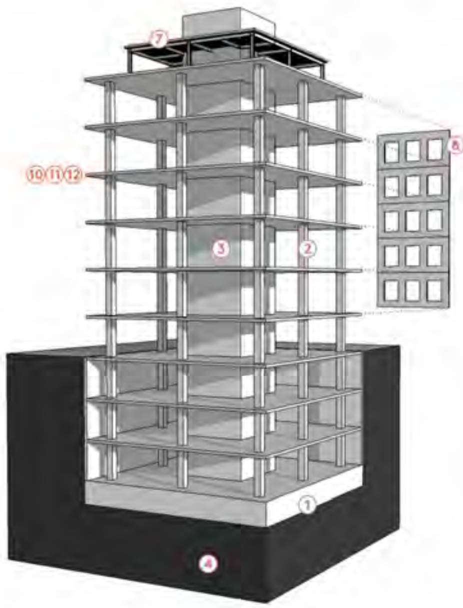
Assuming the Mithun 2022 average for GWP of wood construction for multi-family housing, 120.2 kgCO2/m²

CANDIDATES FOR CEMENT REPLACEMENT



MOST LIKELY
(35%-80% Replacement Typical)
-Delayed formwork stripping acceptable
-Low early strength acceptable

1) Mat Slabs + Footings + Slabs on Grade
2) CIP Columns
3) CIP Walls
4) Drilled Piers and Piles
5) Grouting & Mortars
6) Topping Slabs & Housekeeping Slabs
7) Concrete on Metal Deck

VARIABLE
(15%-50% Replacement Typical)
-Reduced color control in precast face mixes
-Backup mixes in precast are usually acceptable candidates
-Delayed formwork stripping may be an issue without face mix

8) Precast Elements - Cladding
9) Precast Elements - Structural

MOST CHALLENGING
(15%-35% Replacement Typical)
-Delayed formwork stripping can impact construction schedule
-Low early strength can impact construction schedule

10) Elevated Beams & Slabs
11) Polished Concrete Floors (Densifier Incompatibility)
12) Post-Tensioned Slabs

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03 3000-ALT - CAST-IN-PLACE CONCRETE – 40% REDUCTION

A. The section to be used in place of Base Design Criteria 03 3000. Provide and install concrete products with an overall reduced weighted-average Global Warming Potential (GWP) impact reduction of 40% below baseline, as defined in ALT 02.A and ALT 02.B.

TABLE 1. BASELINE GWP FOR CONCRETE MIX DESIGNS

Min. Design Strength* *psi*	**Baseline GWP** *kg CO2e per yd³*	**Baseline GWP** *kg CO2e per m³*
4000	293	
3500	266	
3000	238	
4000	293	
4500	326	
4000	293	
5000	359	

Design Strength measured at the maximum days of cure time, as designated by the Engineer by component

C. Sustainability Requirements.
1. Provide an Environmental Product Declaration (EPD) identifying the global warming potential (GWP) for each mix design,. The EPD(s) is/are to meet the requirements of Section 01 3329 - Sustainable Design Reporting, Part 4 - Scope 3 Carbon Emissions Tracking. Suppliers are encouraged to maximize reduction in GWP values, provided all performance requirements identified in Appendix 03 3000 - Cast-in-Place Concrete are met and mock-ups of slabs are performed to the satisfaction of the Engineer.
2. The total Global Warming Potential (GWP) of the project's concrete (Project GWP) must demonstrate an overall reduction of **40%** below the Baseline GWP (Table 1). This total reduction is to be calculated on a volume-weighted basis, with each mix measured against the values in Table 1, averaging across all concrete poured.
3. Project GWP is calculated as the summation of the product of each mix-specific GWP and the placed volume of that mix.
4. The Baseline GWP is calculated as the summation of the product of each mix's Baseline GWP and the placed volume of each mix.
5. The Project GWP may be calculated with a different volume than the Baseline GWP volume if the Project GWP is reduced by reducing overall volume for a building component or application. In such cases, Contractor must provide supporting documentation per the Submittals requirements in this section.

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Questions for your structural engineer:

- **How do you limit the GWP of concrete?** (ask at the proposal/interview stage!)
- **Do your concrete specifications**
  - Set maximum (not minimum) cement content /embodied carbon (aka GWP)
  - Specify latest day to strength (ie 56 or 90 days vs. 7 or 28 wherever possible)
  - Separate out mix types (foundations vs. columns vs. suspended slabs)
  - Avoid overly prescriptive specs in order to maximize options for subs/suppliers
- **Do you COLLABORATE to find the lowest GWP sweet-spot?**

Questions for your General Contractor:

- **Have you reviewed the concrete specifications on this project yet?**
- **Can concrete subcontractor and supplier on this job provide feedback?**
- **What constructability issues do you anticipate? (pumpability, curing time, etc.)**

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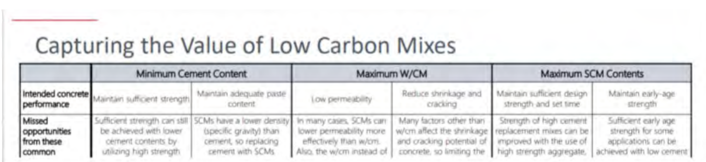
Where to go for some help:

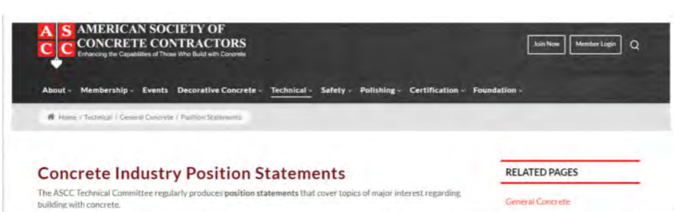
- **Specification Guide** for Low Carbon Concrete Mixes by U.S. Concrete
  https://bit.ly/3AQEh3x



Capturing the Value of Low Carbon Mixes

	Minimum Cement Content		Maximum W/CM		Maximum SCM Contents	
Intended concrete performance	Maintain sufficient strength	Maintain adequate paste content	Low permeability	Reduce shrinkage and cracking	Maintain sufficient design strength and set time	Maintain early-age strength
Missed opportunities from these common	Sufficient strength can still be achieved with lower cement contents by utilizing high strength	SCMs have a lower density (specific gravity) than cement, so replacing cement with SCMs	In many cases, SCMs can lower permeability more effectively than w/cm. Also, the w/cm instead of	Many factors other than w/cm affect the shrinkage and cracking potential of concrete, so limiting the	Strength of high cement replacement mixes can be improved with the use of high strength aggregate.	Sufficient early age strength for some applications can be achieved with low cement

- **American Society of Concrete Contractors** Position Statements
  https://ascconline.org/Technical/General-Concrete/Position-Statements



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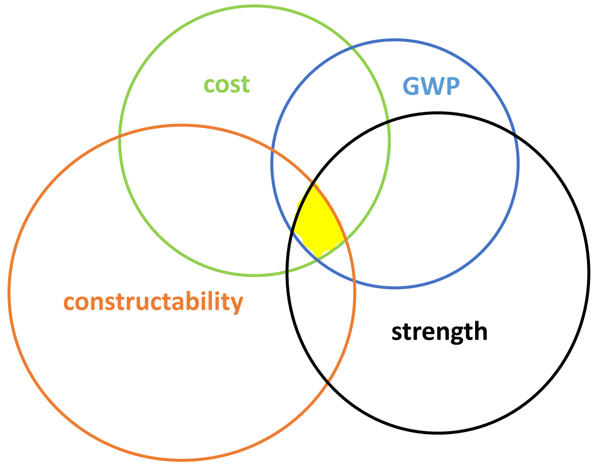
The Sweet Spot

Tee up concrete sub, concrete supplier, structural engineer, architect and builder to **collaborate** at submittal phase on final mix designs that are:

- Meeting architectural requirements
- Cost neutral, i.e. within bid cost
- Appropriate strength
- Appropriate curing time, pumpability, finishing etc.
- Low cement i.e. low GWP



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Action Steps

to Reduce Embodied Carbon in Concrete

1. Ask questions early
2. Specify right
3. Encourage multi-sector collaboration

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Thank you!

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