Lower Carbon Concrete: Market Drivers and Best Practices
WA ACI Chapter Meeting | April 21, 2021

Dave Walsh
Director of Sustainability | Sellen Construction

Image credit: Sellen
Materially Important: concrete’s essential role and unique ability to optimize
Concrete: Materially Important

- World’s most common building material
- Ability for Architectural and Structural Expression
- Durability and Strength
- A Leader in Material Disclosure
- Key role in Infrastructure
- Exponential worldwide growth in use
- Ability to be carbon optimized

Worldwide Cement Use

Cement usage 1980-2017: a proxy for dramatic increase of concrete usage

Source: Decarbonizing Concrete Report, March 2021

Image credit: bernerzeitung.ch
What: Carbon, defined

“Carbon” = Greenhouse Gases

- **Carbon Dioxide (CO₂)**
  - Fossil Fuel Combustion
    (Coal, Natural Gas, Gasoline, Diesel...)
  - Natural Sources
  - Process Emissions
- **Other Greenhouse Gases:**
  - Methane (CH₄)
    - Landfills
    - Agriculture
    - Natural Gas Systems
  - Nitrous Oxides (N₂O)
    - Car Emissions
    - Soils Management
    - Manufacturing
- Hydrofluorocarbons (HFCs)
  - Refrigerants
  - Manufacturing
- Perfluorocarbons (PFCs)
  - Aluminum Production

Embodied Carbon: Emissions related to a material’s lifecycle

Operational Carbon: Emissions from building operations
When:
Life Cycle Stages when carbon is emitted

Embodied Carbon

A1 to A3: Product Manufacturing
Extraction/Harvest (Cradle) to Factory Gate

A4 to A5: Transport to Jobsite
Construction Activity

Operational Carbon

B: Use Stage
Energy and Water Use

Embodied Carbon

C: End of Life Stage
Deconstruction/Demo/Disposal (Grave)

Embodied Carbon

D: Potential Recovery,
Reuse or Recycle
How: The opportunity to replace conventional cement

Concrete is essential to our daily lives. Its primary component, cement, releases significant emissions accounting for 5 percent or more of global greenhouse gas emissions (GHGs). Let’s reduce that number:

1. Cement begins its life as crushed limestone.
2. It is mixed with raw materials and heated in a kiln at 2732 degrees Fahrenheit.
3. Clinker is cooled and ground into a fine powder.

Turning down the heat: How greener concrete is manufactured

- **Harmful Emissions:** The majority of GHG emissions released from cement are caused by the chemical reaction of turning limestone to clinker. They also come from the fuel needed to fire the kiln.
- **Emissions Reduction:** To lessen the amount of cement needed — thereby reducing the overall GHG emissions produced from the cement formation — slag, fly ash or other supplementary materials can be added to the powder mix in lieu of a portion of cement.

Finally, the cement powder is mixed with other materials, thus becoming concrete for use in construction.

Image credit: Sellen
How: GHG Reduction Opportunities: Manufacturing (and decisions prior manufacturing)

### Strategies Prior to Manufacturing:

- Structural System Selection
- Informed Target Setting
- Material efficient design
- Performance Specs
- Informed Instructions to Bidders

### Manufacturing Strategies:

- Type 1L (PLC) Cement Use when allowed
- Supplementary Cementitious Material (SCM) Use
- Recycled Aggregate (RCA) Use when allowed
How:
GHG Reduction Opportunities: Transport and Construction Activity

Transport and Construction Management Strategies:

- Reduction of Jobsite Wait Time
- Electronic Ticketing to validate Carbon Reduction Forecast
- Maturity Meters to confirm strength and fine tune mix selection avoiding unnecessary emissions
How:
GHG Reduction Opportunities: Future Reuse

<table>
<thead>
<tr>
<th>Embodied Carbon</th>
<th>A1 to A3</th>
<th>Product Manufacturing</th>
<th>Extraction/Harvest (Cradle) to Factory Gate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embodied Carbon</td>
<td>A4 A5</td>
<td>Transport to Jobsite</td>
<td>Construction Activity</td>
</tr>
<tr>
<td>Operational Carbon</td>
<td>B</td>
<td>Use Stage</td>
<td>Energy and Water Use</td>
</tr>
<tr>
<td>Embodied Carbon</td>
<td>C</td>
<td>End of Life Stage</td>
<td>Deconstruction/Demo/Disposal (Grave)</td>
</tr>
<tr>
<td>Embodied Carbon</td>
<td>D</td>
<td>Potential Recovery, Reuse or Recycle</td>
<td></td>
</tr>
</tbody>
</table>

Recycle and Reuse Strategies:

- Design for Material Recovery
- Recycling of Demolished Materials
- Recycled Concrete Aggregate (RCA) Manufacturing
- RCA permitted in specs for next project
Market Drivers:
the increasing demand to measure and reduce carbon

Image credit: NASA
Private Businesses, Public Commitments

Amazon's Climate Pledge

Amazon: Commits to net zero carbon by 2040 and 100% renewable energy by 2030

Announced: September 19, 2019

Microsoft's Climate Commitment

Microsoft:
- By 2030: Carbon negative,
- By 2050: MS will remove all carbon the company has emitted since 1975
- Zero Carbon Certification for Project

Announced: January 13, 2020
Embodied Carbon in Sustainability Certifications

**Zero Carbon Certification**
International Living Future Institute

**Lower Carbon Materials:**

- The embodied carbon emissions impact of the primary materials of the foundation, structure, and enclosure have been reduced by a minimum of 10%, compared to baseline scenario.

- The total embodied carbon emissions of the project must not exceed 500 kg CO₂e/m² (for the covered categories).

**LEED v4.0/v4.1**

- **Building Life-Cycle Impact Reduction**
  Credit MRc1

- **Procurement of Low Carbon Construction Materials**
  Pilot Credit MRpc132
Available Embodied Carbon Software Tools

**Athena Impact Estimator**
- **Confirming early design decisions**

**Good For:**
- Early Concept
- No Drawings, just quantities
- Early Structural Systems Options
- It's easy to use
- It's Free!

**Limitations:**
- Limited Database of Materials
- No ability to fine-tune with specified EPDs
- Doesn't cover all categories

**Tally**
- **Holistic understanding of design decisions**

**Good For:**
- Entire project phases: concept to final design
- Extensive Database – can fill the gaps where no EPD exists
- Can update GHG values with specific EPDs in post-processing

**Limitations:**
- Requires somewhat granular BIM Modeling
- Hard to accommodate multiple BIM models from different design teams
- Requires some training to use
- Cost

**EC3**
- **Product selection and procurement decisions**

**Good For:**
- Entire project phases: concept to final design
- Easy to use – BOM data entry
- Understand how a specific product compares with baselines
- It’s Free!

**Limitations:**
- Database is growing, but gaps exist
- Includes just A1-A3 impacts for GHG
- Apples-to-apples comparisons sometimes not possible
- Cost
The Trend Line is Clear

Annual GHG Readings – Mauna Loa Observatory, Big Island

Image credit: Dave Walsh
Building Materials Play a Significant Role in Total Greenhouse Gas Emissions

Annual Global CO₂ Emissions

- Building Operations: 28%
- Industry: 30%
- Transportation: 22%
- Other: 9%

Building Materials and Construction: 11% of global emissions

Source: UN Environment Global Status Report 2017
Data Source: IEA (2017), World Energy Statistics and Balances

Image Credit: Architecture 2030
Embodied Carbon vs Operational Carbon
Over a 30 Year Period – Business as Usual Building Efficiency

Cumulative Total Carbon Emissions of a Single Building
Global Average Building Carbon Footprint: Business as Usual


Image Credit: Architecture 2030
Embodied Carbon vs Operational Carbon

Over a 30 Year Period – Energy Efficient Buildings

Cumulative Total Carbon Emissions of a Single Building

Global Average Building Carbon Footprint: 50% Better Operational Performance


Image Credit: Architecture 2030
Embodied Carbon vs Operational Carbon

By the Critical Date of 2030: Embodied Carbon is the Urgent Concern

Cumulative Total Carbon Emissions of a Single Building

Global Average Building Carbon Footprint: 50% Better Operational Performance


Image Credit: Architecture 2030
Legislation on the Horizon:
carbon disclosure of structural materials is coming
State of Embodied Carbon Legislation in the USA

- Adopted or Pending Legislation in 9 States
- Action happening at the State, County and City levels
- Most, but not all affect concrete disclosure
- Legislation generally falls into two categories:
  - Track and disclose embodied carbon using third-party verified mix specific EPDs
  - Track, disclose and emit less than a legislated emissions cap
- Applicability varies: from pilots impacting a few projects to all public and private projects

Image credit: Carbon Leadership Forum
**Embodied Carbon Legislation/Public Policy Overview affecting Concrete**
does not include: private owner initiatives/policy or public policy under consideration but not yet introduced or implemented. Data as of 4/19/21

<table>
<thead>
<tr>
<th>State</th>
<th>Legislation Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WA</td>
<td>EPDs and Embodied Carbon Disclosure Required</td>
<td>City of Seattle Expedited Permitting for EPDs</td>
</tr>
<tr>
<td>CA</td>
<td>EPDs +Disclosure Required + Max GHG Cap or Cap Phase-in Required</td>
<td>Marin County Low Carbon Concrete Code</td>
</tr>
<tr>
<td>WA</td>
<td>Applied to all Projects</td>
<td>HB 2608 Buy Clean Buy Fair WA</td>
</tr>
<tr>
<td>CA</td>
<td></td>
<td>AB 1365 Public Contracts Clean Conc.</td>
</tr>
<tr>
<td>OR</td>
<td></td>
<td>AB 1369 Expands Buy Clean CA to Conc</td>
</tr>
<tr>
<td>MN</td>
<td></td>
<td>B3 Requirements LCA Modeling and EPDs</td>
</tr>
<tr>
<td>NJ</td>
<td></td>
<td>Assembly Bill S253 Low EC Conc. Tax Credits</td>
</tr>
<tr>
<td>NY</td>
<td></td>
<td>SB S542 Low EC Conc. Leadership Act</td>
</tr>
<tr>
<td>NY</td>
<td></td>
<td>Or SB 159 (2020) GWP for Public Project Matls</td>
</tr>
<tr>
<td>NY</td>
<td></td>
<td>CLEAN Future Act Federal Buy Clean Program</td>
</tr>
<tr>
<td>OR</td>
<td></td>
<td>City of Portland Rqmts for Approved Mixes</td>
</tr>
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<td></td>
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</tr>
<tr>
<td>WA</td>
<td>Pilot: Limited Projects</td>
<td>Sound Transit EPDs on Select Projects</td>
</tr>
<tr>
<td>CA</td>
<td></td>
<td>Port Authority of NY &amp; NJ Clean Construction Program</td>
</tr>
<tr>
<td>NY</td>
<td></td>
<td>CLEAN Future Act Federal Buy Clean Program</td>
</tr>
<tr>
<td>NJ</td>
<td></td>
<td>CLEAN Future Act Federal Buy Clean Program</td>
</tr>
</tbody>
</table>

Legislation Key: Green: Legislation Passed & Law | Gray: Legislation Introduced

Image credit: Sellen
Baseline and Targets:
measuring GHG and different approaches to setting reduction goals
EPD: Environmental Product Declaration
the “food label” of material impacts

EPDs can be:
• Industry-wide average or
• Product-specific (for a specific mix from a specific plant) and
• Third-party reviewed (meeting ISO guidelines) or
• Not third-party reviewed
Select your Baseline

“Lower Carbon Concrete” starts with defining a Baseline

Option 1: NRMCA (National Ready Mix Concrete Association) Baseline, 2016

- Widely used reference and widely understood
- Has both National and Regional Data
- Is not application specific, so not always a fair comparison
- Does not include strengths above 8000 psi

Option 2: Carbon Leadership Forum, 2019 (updated 2021)

- Published, November 2019
- Has published low, average and high baselines, be clear which to use
- Works with EC3
- No regional averages

Table 1: Pacific-Northwest (CA, Oregon)

<table>
<thead>
<tr>
<th>Ready Mixed Concrete</th>
<th>Low</th>
<th>Avg.</th>
<th>High</th>
<th>Declared unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>2500 psi</td>
<td>230</td>
<td>290</td>
<td>380</td>
<td>m3</td>
</tr>
<tr>
<td>3000 psi</td>
<td>290</td>
<td>320</td>
<td>420</td>
<td>m3</td>
</tr>
<tr>
<td>4000 psi</td>
<td>310</td>
<td>390</td>
<td>520</td>
<td>m3</td>
</tr>
<tr>
<td>5000 psi</td>
<td>380</td>
<td>490</td>
<td>640</td>
<td>m3</td>
</tr>
<tr>
<td>6000 psi</td>
<td>400</td>
<td>510</td>
<td>670</td>
<td>m3</td>
</tr>
<tr>
<td>8000 psi</td>
<td>470</td>
<td>620</td>
<td>790</td>
<td>m3</td>
</tr>
</tbody>
</table>
Select your Baseline

Option 3: Custom Baseline from Project-specific Historical Data

- Requires data collection from past applicable projects
- May need to be adjusted for newer cement used
- Can inform a real-world business-as-usual (BAU) baseline
- Is very location specific and very application specific – good for repetitive projects
Option 1. Project-wide Reduction Requirement

- Requirement is a single percentage reduction
- A weighted average for all the concrete
- Each mix is compared to the corresponding baseline for its strength
- Simple to specify but hard to get set goal right
- Allows flexibility for how much each application must reduce
- What’s BAU and what’s ambitious depends on the proportion and types of uses in the project.

Example Specification Language

For a project-wide reduction requirement

Provide concrete mixes such that the percent reduction in weighted average Proposed Mix GWP as compared to the weighted average Benchmark GWP shall be **not less than 30%**.

Calculate the weighted average Benchmark GWP for the volume of concrete corresponding to the Proposed Mix Designs with EPDs as follows:

\[
GWP_{\text{avg, benchmark}} = \frac{\sum_i (GWP_{\text{benchmark},i} \times Volume_i)}{\sum_i Volume_i}
\]

Where:
- \(GWP_{\text{benchmark},i}\) = benchmark global warming potential for concrete class \(i\)
- \(Volume_i\) = volume of concrete for concrete class \(i\)
- \(n\) = total number of classes of concrete

Calculate the weighted average Proposed Mix GWP as follows:

\[
GWP_{\text{avg, proposed}} = \frac{\sum_i (GWP_{\text{proposed},i} \times Volume_i)}{\sum_i Volume_i}
\]

Where:
- \(GWP_{\text{proposed},i}\) = global warming potential for proposed mix \(i\)
- \(Volume_i\) = volume of concrete for proposed mix \(i\)
- \(n\) = total number of proposed mixes of concrete

Calculate the percent reduction in weighted average Proposed Mix GWP as compared to the weighted average Benchmark GWP as follows:

\[
\% \text{ Reduction} = \frac{GWP_{\text{avg, baseline}} - GWP_{\text{avg, proposed}}}{GWP_{\text{avg, baseline}}} \times 100
\]

Example Calculation

<table>
<thead>
<tr>
<th>Application (Use)</th>
<th>Weighted % Below NRMCA 2016</th>
<th>CY in Est % by Vol</th>
<th>Weighted % Below NRMCA</th>
<th>Reduction multiplied % Vol. x Weighted Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilled Shafts, 4k Mix # *********</td>
<td>19.56%</td>
<td>44</td>
<td>0.4%</td>
<td>0.1%</td>
</tr>
<tr>
<td>SOIL, 4k, F0</td>
<td>35.92%</td>
<td>1,004</td>
<td>7.6%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Foundation, 4k, F0 Mix # *********</td>
<td>29.38%</td>
<td>7</td>
<td>0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Foundation, 4k, F1 Mix # *********</td>
<td>29.38%</td>
<td>1,769</td>
<td>13.1%</td>
<td>3.8%</td>
</tr>
<tr>
<td>Curbs/Pads/Retaining Walls, 4.5k, F2 Mix # *********</td>
<td>33.35%</td>
<td>721</td>
<td>5.3%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Basement Walls and Basement Foundations, 5k Mix # *********</td>
<td>39.63%</td>
<td>0</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Mild &amp; PT Slab/Reef, 6k Mix # *********</td>
<td>42.05%</td>
<td>4,243</td>
<td>46.2%</td>
<td>19.5%</td>
</tr>
<tr>
<td>Columns/Shear Walls/Basement Walls, 6k Mix # *********</td>
<td>43.13%</td>
<td>1,600</td>
<td>12.0%</td>
<td>5.2%</td>
</tr>
<tr>
<td>Shotcrete--Tunnel and Basement Walls, 6k Mix # *********</td>
<td>18.34%</td>
<td>555</td>
<td>4.1%</td>
<td>0.8%</td>
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<tr>
<td>Shear Wall/Columns, SCC, 8k Mix # *********</td>
<td>48.81%</td>
<td>1,523</td>
<td>11.3%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Shear Wall/Columns, SCC, 10k Mix # *********</td>
<td>43.25%</td>
<td>0</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Goal is 30%
**Set the Reduction Goal**

**Option 2: Required Reductions for each Application**

- Requires a minimum reduction or required reduction ranges specific to each application
- Requires a good knowledge of what's possible for each application
- Does not allow flexibility for the supplier and contractor

Focus reduction effort on the applications (uses) with the highest volumes

<table>
<thead>
<tr>
<th>Test Age (days)</th>
<th>APPLICATION</th>
<th>Priority for Targeting Reductions</th>
<th>c’f (psi)</th>
<th>Compressive Strength Used for Baseline (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Basement Walls</td>
<td>Low</td>
<td>505</td>
<td>455.53</td>
</tr>
<tr>
<td>6000/8000</td>
<td>Columns</td>
<td>Medium</td>
<td>530</td>
<td>480.03</td>
</tr>
<tr>
<td>56</td>
<td>Conc on Slab Deck</td>
<td>Low</td>
<td>15</td>
<td>366.73</td>
</tr>
<tr>
<td>28</td>
<td>Carts, path</td>
<td>Low</td>
<td>0</td>
<td>411.13</td>
</tr>
<tr>
<td>28</td>
<td>Foundations</td>
<td>High</td>
<td>305</td>
<td>366.73</td>
</tr>
<tr>
<td>56</td>
<td>MHD sides</td>
<td>Medium</td>
<td>365</td>
<td>480.08</td>
</tr>
<tr>
<td>56</td>
<td>FT Slabs</td>
<td>High</td>
<td>4605</td>
<td>480.08</td>
</tr>
</tbody>
</table>

The required design strength determines which NRMCA baseline is used

Research similar projects with the same application, strength to set min. reduction

Consider setting a stretch goal for each application. Be realistic for each condition

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<thead>
<tr>
<th>APPLICATION</th>
<th>Priority for Targeting Reductions</th>
<th>c’f (psi)</th>
<th>Test Age (days)</th>
<th>Baseline</th>
<th>Compressive Strength</th>
<th>Required Min. Goal</th>
<th>Required Min. Target</th>
<th>Stretch Goal</th>
<th>Stretch Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement Walls</td>
<td>Low</td>
<td>505</td>
<td>28</td>
<td>455.53</td>
<td>5000</td>
<td>0%</td>
<td>455.53</td>
<td>-10%</td>
<td>409.88</td>
</tr>
<tr>
<td>Columns</td>
<td>Medium</td>
<td>530</td>
<td>6000/8000</td>
<td>480.03</td>
<td>6000</td>
<td>-35%</td>
<td>312.02</td>
<td>-50%</td>
<td>240.02</td>
</tr>
<tr>
<td>Conc on Slab Deck</td>
<td>Low</td>
<td>15</td>
<td>56</td>
<td>366.73</td>
<td>4000</td>
<td>-35%</td>
<td>238.37</td>
<td>-40%</td>
<td>220.04</td>
</tr>
<tr>
<td>Carts, path</td>
<td>Low</td>
<td>0</td>
<td>28</td>
<td>411.13</td>
<td>6000</td>
<td>-35%</td>
<td>267.23</td>
<td>-50%</td>
<td>205.57</td>
</tr>
<tr>
<td>Foundations</td>
<td>High</td>
<td>305</td>
<td>28</td>
<td>366.73</td>
<td>4000</td>
<td>-45%</td>
<td>201.70</td>
<td>-70%</td>
<td>110.02</td>
</tr>
<tr>
<td>MHD sides</td>
<td>Medium</td>
<td>365</td>
<td>56</td>
<td>480.08</td>
<td>6000</td>
<td>-40%</td>
<td>288.05</td>
<td>-55%</td>
<td>216.04</td>
</tr>
<tr>
<td>FT Slabs</td>
<td>High</td>
<td>4605</td>
<td>56</td>
<td>480.08</td>
<td>6000</td>
<td>-20%</td>
<td>345.66</td>
<td>-40%</td>
<td>288.01</td>
</tr>
</tbody>
</table>
Set the Reduction Goal

Option 3: An “Open Ended “ Reduction Requirement

- You (the supplier) tell us what the maximum reduction is
- Requires giving enough performance based with over encumbering with constraints
- Requires active participation of General Contractor to provide constructability and schedule information
- Requires trusted and experience partners

With the criteria provided...
recommend the supplier’s most carbon-efficient mix for each application

Design Team Criteria
(for each application)

- Min. Design Strength (f’c)
- Exposure Class
  Note: w/cm ratio not specified
- Maximum Shrinkage
- Maximum Aggregate Size
- Modulus of Elasticity
- Is Recycled Aggregate Allowed
- Will it be Polished?

General Contractor Criteria
(for each application)

- Early Strength (Required to jump forms)
- Anticipated Time of Placement (during the day)
- Test Age (where appropriate consider extending beyond 28 days)
- Overall Project Schedule
- Method of Placement (Pumped? Bucket? Shotcrete?)
- Pump Distance
- Pump Rate
Procurement 2.0: carbon as a selection criteria
<table>
<thead>
<tr>
<th></th>
<th>Conventional Procurement</th>
<th>&quot;Procurement 2.0&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural Systems Decision:</strong></td>
<td>• Embodied carbon of alternative systems not modeled at concept design</td>
<td>• Design Team and/or general contractor models carbon implications of various structural systems using concept level Bill of Materials</td>
</tr>
<tr>
<td><strong>Carbon Reduction Goals:</strong></td>
<td>• None</td>
<td>• Defined or Supported by the Owner</td>
</tr>
<tr>
<td><strong>Specifications Approach:</strong></td>
<td>• Prescriptive based</td>
<td>• Performance based</td>
</tr>
<tr>
<td></td>
<td>• w/c ratio defined in specs/general notes</td>
<td>• w/c ratio defined by ACI and not determined by general notes</td>
</tr>
<tr>
<td></td>
<td>• Blended Cements not permitted</td>
<td>• Blended Cements Permitted</td>
</tr>
<tr>
<td></td>
<td>• SCMs Capped or not permitted</td>
<td>• SCMs Permitted</td>
</tr>
<tr>
<td></td>
<td>• No EPDs required at time of bid</td>
<td>• RCA Permitted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• EPDs required at time of bidding</td>
</tr>
</tbody>
</table>
## Conventional Procurement vs “Procurement 2.0”

<table>
<thead>
<tr>
<th>Designer/Contractor Coordination</th>
<th>Design Team/Contractor Coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>• No coordination prior to Issued for Construction Drawings</td>
<td>• Optimization opportunities discussed at design development</td>
</tr>
<tr>
<td>• Identify tricky areas affecting mix selection: polished concrete, rebar congestion, white concrete</td>
<td></td>
</tr>
</tbody>
</table>

### Timing of Concrete Supply Bidding

<table>
<thead>
<tr>
<th>Timing of Concrete Supply Bidding</th>
</tr>
</thead>
<tbody>
<tr>
<td>• After design is complete</td>
</tr>
<tr>
<td>• During design</td>
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</tbody>
</table>

### Instructions to Bidders

<table>
<thead>
<tr>
<th>Instructions to Bidders</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Minimal construction schedule info</td>
</tr>
<tr>
<td>• Little or no information on pumping distances and pumping rates</td>
</tr>
<tr>
<td>• No requirements for EPD</td>
</tr>
<tr>
<td>• Detailed construction schedule info</td>
</tr>
<tr>
<td>• Pumping distances and pump rate</td>
</tr>
<tr>
<td>• Detailed Info on early strength requirements for jumping forms</td>
</tr>
<tr>
<td>• EPDs for all mixes required with bid</td>
</tr>
<tr>
<td>• Provide Conventional Mix Solution and Carbon Optimized Mix Solution</td>
</tr>
</tbody>
</table>
Conventional Procurement vs “Procurement 2.0”

**Instructions to Bidders (continued)**
- All applications have 28 day f’c maturity
- No alternative bids requested with extended maturity dates

**Instructions to Bidders (continued)**
- Two sets of mix solutions requested:
  - Conventional 28 day maturity
  - Carbon Optimized: extended maturity dates for some applications

**Decision Criteria and Information presented to Owner for Bid Award**
- Cost
- Availability
- Successful Previous Working Experience

**Decision Criteria and Information presented to Owner for Bid Award**
- Cost
- Availability
- Successful Previous Working Experience
- Amount of GHG reduction possible by using some or all of the carbon-optimized mixes
The Best Mix:
General contractor, supplier and design team as allies in GHG reduction
Use Blended Cement

Use Type 1L Cement
(aka PLC or Portland Limestone Cement)

- Immediate 10% -12% embodied GHG reduction compared to Type I
- Compatible with existing mixes
- Widely available in this region
- Widely accepted by DOTs, Sound Transit (many applications), CalTrans (pending)
- Some product specific EPDs = supply chain specific data = lower GHG data in EC3
- Long History of Successful Use: First in Germany in 1965
- Jurisdictions, not Science, is the limiter: Europe allow up to 35% limestone blended with cement

Calcination Process:
Limestone at high heat releases significant CO2

Harmful Emissions:
The majority of GHG emissions released from cement are caused by the chemical reaction of turning limestone to clinker. They also come from the fuel needed to fire the kiln.

With PLC, about 10% - 15% does not go through kiln and does not have calcination emissions

* Inputs and outputs simplified for clarity
Do this, then...

1. Consider carbon implications of the type of concrete structural system
2. Be economical with the design; reduce quantities where possible
3. Use Performance Specification and remove prescriptive requirements
4. Allow Type 1L Cement in Specs and General Notes and use Supplement Cementitious Materials (Slag or Fly Ash)
5. Allow Recycled Aggregate where appropriate
6. Communicate Design and Constructability Criteria to Supplier during the bidding process

....then what: go further with Data and Technology
Dial it In: Maturity Meters

Maturity Meters

- Allows for accurate strength readings by tracking temperature
- Avoids the inaccuracy of mishandled testing cylinders
- Bluetooth sensors can push data to team and alert when key values are reached
- Informs team what mix is doing the job – potentially forestalling switching to richer mix

Install Bluetooth monitors. Pour concrete

Remote measurement of concrete temperature

Each mix has a unique temperature to strength curve
Forecast and Track: Electronic Ticketing

Electronic Ticketing

- Moves us to the digital age – efficiency boon
- Digital format allows near-live time tracking of quantities, mixes. Paired with EPD info this builds a JTD carbon emissions picture
- Provides a stream of new data like truck wait times – another opportunity for GHG reduction
- Can export to Excel or Power BI for analytics such as tracking forecasted emissions to actual
- If not tracking the plan, we can ask “why” early enough to change course
- No longer “resultant sustainability” but predictive sustainability

Analysis to:
- Reduce Idling Time
- Track Optimized Mix Use
Key Takeaways:

- There are client, business and legislative drivers for lower carbon concrete in this market.
- The demand for material disclosure (EPDs) is growing and in some projects mix-specific EPDs are required.
- Today there are implementable and meaningful strategies to reduce emissions from concrete.
- By designers providing performance specifications and contractors providing more constructability information at bid time, suppliers can provide carbon optimized solutions.
- Beyond the mix, there are jobsite strategies to fine tune construction operations and further reduce emissions.
Thanks

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Sellen Construction