Today's Discussion

- Why Blended Cements
- Blended Cement Basics
- Anticipated Performance of Blended Cements
  - & best practices for implementation
Low Carbon Concrete use is being driven by a Combination of Regulatory Requirements, Certification Schemes, and a Growing Awareness

Federal "Buy Clean" Policies
- Executive Order 14057 - Net Zero Goal in Federal Procurement
- Inflation Reduction Act
- EPA EPD grants & label programs
- USDOT & General Services Administration Buy Clean Initiative
- prioritize the use of lowercarbon construction materials

Green Building Certification
- LEED, BREEAM, and others require or award points for products with EPDs
- Incentivizes construction companies to ask for EPDs

Increased awareness
- Growing awareness of the environmental impact of construction, both in terms of operational energy use and embodied carbon.

State & City "Buy Clean" Policies
- CA, CO, & OR - Legislated
- WA, MN, IL, VA, MD, NJ & DE - Considering
- Portland OR, San Francisco Bay Area, Marian County, CA, others

Life Cycle Assessment (LCA)
- The use of LCA in the construction industry is increasing
- EPDs provide a standardized and consistent way to report results for building products.

Sustainability Goals
- Building owners / developers are increasingly setting ambitious goals,
- EPDs provide a transparent and credible way to evaluate products.

GSA Low Carbon Concrete Requirements
FHWA – will be similar to GSA, but wants to regionalize data based on NRMCA Regions

Construction product assemblies (e.g. rebar-reinforced concrete, concrete made with qualifying cement) qualify for IRA funding if at least 80% of the assembly’s total cost or total weight comprises materials that meet these Requirements

Requires:
- A product-specific Type III (third-party verified) EPD
- Where feasible, EPDs must rely on facility-specific data rather than industry or manufacturer average data.
- If a facility-specific EPD data for the material’s most greenhouse-gas intensive processes (cement) is unavailable, an EPD without such data is sufficient.

<table>
<thead>
<tr>
<th>Specified concrete strength class (compressive strength [f'c] in pounds per square inch [PSI])</th>
<th>Top 20% Limit</th>
<th>Top 40% Limit</th>
<th>Better Than Average Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤2499</td>
<td>228</td>
<td>261</td>
<td>277</td>
</tr>
<tr>
<td>3000</td>
<td>257</td>
<td>291</td>
<td>318</td>
</tr>
<tr>
<td>4000</td>
<td>284</td>
<td>326</td>
<td>352</td>
</tr>
<tr>
<td>5000</td>
<td>305</td>
<td>357</td>
<td>382</td>
</tr>
<tr>
<td>6000</td>
<td>319</td>
<td>374</td>
<td>407</td>
</tr>
<tr>
<td>≥7200</td>
<td>321</td>
<td>362</td>
<td>402</td>
</tr>
</tbody>
</table>

Add 30% to these numbers for GWP limits where high early strength concrete mixes are required for technical reasons.
Government Agencies are requiring reduced carbon emissions.

Colorado legislation mandated construction materials manufacturers to label their products with their embodied carbon starting in 2025. The law charges CDOT with setting benchmarks for now, and then with creating policies to lower the carbon footprint of the purchased goods as much as possible, starting in 2025.

**Colorado DOT Is Requiring EPDs & Setting CO2 Benchmarks for Construction Products to take effect January 2025**

**State & Local Embodied Carbon Policies**

Currently, 24 States plus DC have adopted GHG Reduction Targets
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Private Industry is demanding reduced carbon emissions.

Major Developers are on a Mission to Reduce their CO2 Footprint
Private Industry is demanding reduced carbon emissions.

Major Developers are on a Mission to Reduce their CO2 Footprint

<table>
<thead>
<tr>
<th>Mix Purpose</th>
<th>PSI</th>
<th>XXXXX Baseline kg CO2e/yc03</th>
<th>XXXXX Target - 40% GWP Reduction kg CO2e/yc03</th>
<th>CY Total In Project</th>
<th>XXXXX Baseline Total kg CO2e</th>
<th>XXXXX Target Total - 40% GWP Reduction kg CO2e/yc03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard duty pavement</td>
<td>4000</td>
<td>293</td>
<td>176</td>
<td>23800</td>
<td>6,973,400</td>
<td>4,188,800</td>
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<tr>
<td>Medium duty pavement</td>
<td>4000</td>
<td>293</td>
<td>176</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Heavy duty pavement</td>
<td>4000</td>
<td>293</td>
<td>176</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Extra heavy-duty pavement</td>
<td>4000</td>
<td>293</td>
<td>176</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SLAM platforms and suspended slabs</td>
<td>3500</td>
<td>266</td>
<td>160</td>
<td>10000</td>
<td>266,000</td>
<td>160,000</td>
</tr>
<tr>
<td>Foundations</td>
<td>3000</td>
<td>238</td>
<td>143</td>
<td>3000</td>
<td>714,000</td>
<td>429,000</td>
</tr>
<tr>
<td>Interior slabs-on-ground</td>
<td>4000</td>
<td>293</td>
<td>176</td>
<td>15000</td>
<td>4,395,000</td>
<td>2,640,000</td>
</tr>
<tr>
<td>Walks and curbs</td>
<td>4500</td>
<td>326</td>
<td>196</td>
<td>1700</td>
<td>554,200</td>
<td>333,200</td>
</tr>
<tr>
<td>Tilt-up walls</td>
<td>4000</td>
<td>293</td>
<td>176</td>
<td>5000</td>
<td>1,465,000</td>
<td>880,000</td>
</tr>
<tr>
<td>Tilt-up walls</td>
<td>5000</td>
<td>359</td>
<td>215</td>
<td>1500</td>
<td>538,500</td>
<td>322,500</td>
</tr>
</tbody>
</table>

Total GWP (kgCO2e) - Embodied Carbon Footprint: $51,000
Total Carbon Reduction from XXXXX baseline: 40%

PCA ROADMAP TO CARBON NEUTRALITY
Committed to achieving carbon neutrality across the value chain by 2050

- **Clinker**: Key chemically reactive ingredient
- **Cement**: The binder
- **Concrete**: Critically useful material to society
- **Construction**: Service life use phase impacts
- **Carbonation**: Concrete to a CO2 sink

**AT THE CEMENT PLANT**
- Increase the use of decarbonated raw materials
- Decrease the use of traditional fossil fuels by 5X
- Increase the use of alternative fuels
- Push efficiency and decrease energy intensity for one metric ton of clinker
- Utilize carbon capture to avoid the release of CO2 emissions
- Reduce clinker production emissions

**OPTIMIZING THE DESIGN AND CONSTRUCTION OF THE BUILT ENVIRONMENT**
- Lower concrete manufacturing emissions to zero at the plant
- Transition to zero emission fleets
- Optimize concrete mix
- Reduce overdesign
- Construct concrete structures for durability, resilience, stiffness, and thermal mass benefits

**CONCRETE IN USE**
- The amount of CO2 that concrete buildings, structures, and pavements can permanently absorb from the air is 10% per year.
- A reduction of 46.5 million metric tons of CO2 emissions per year could be realized if the entire U.S. road system used concrete pavement according to the MIT Concrete Sustainability Hub (MIT CSHub)

https://www.cement.org/sustainability/roadmap-to-carbon-neutrality
The ultimate goal for Cemex Global is to deliver only net-zero CO$_2$ concrete by 2050. Our 2030 goals ensure we are on the right track.

We have the most ambitious goals in the industry.

**2030 Goals**

- To be below 476 kg of CO$_2$ per ton of cementitious material, equivalent to a 40% reduction.*
- To reduce the carbon content per cubic meter of concrete by 165 kg, equivalent to a 35% reduction.*
- To reach 55% in clean energy consumption for a 43% reduction of indirect emissions.**

*According to our 1990 baseline.
**According to our 2020 baseline.

**Global Alignment and Validation**

- Our 2023 goals are aligned with the Science Based Targets Initiative (SBTi) commitments made by Cemex under the Well Below 2°C Scenario.
- Our 2050 goal aligns with the Business Ambition for 1.5°C.
- We have joined the Race to Zero campaign from the United Nations.

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**Balcones (Central TX) Global Warming Potential of Cement**

Balcones TY I/11 vs PLC

**Life Cycle Assessment**

Balcones Cement Products¹, bulk shipped: Type I/II, Type IL per 1 metric tonne.**

<table>
<thead>
<tr>
<th>Impact Assessment</th>
<th>Unit</th>
<th>Type IL</th>
<th>Type I/II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global warming potential (GWP)²</td>
<td>kg CO$_2$ eq</td>
<td>756</td>
<td>816</td>
</tr>
<tr>
<td>Depletion potential of the stratospheric ozone layer (ODP)</td>
<td>kg CFC-11 eq</td>
<td>8.7E-06</td>
<td>9.34E-06</td>
</tr>
<tr>
<td>Eutrophication potential (EP)</td>
<td>kg N eq</td>
<td>2.59E-01</td>
<td>2.74E-01</td>
</tr>
<tr>
<td>Acidification potential of soil and water sources (AP)</td>
<td>kg SO$_2$ eq</td>
<td>1.40</td>
<td>1.50</td>
</tr>
<tr>
<td>Formation potential of tropospheric ozone (POCP)</td>
<td>kg O$_3$ eq</td>
<td>30.8</td>
<td>33.1</td>
</tr>
</tbody>
</table>

2030 Target = 475
CEMEX Roadmap to our CO2 emissions reduction in Goals

**Contribution to 2030 Goal (%)**
- Clinker: 32%
- Decarbonated Raw Materials: 16%
- Low-Temperature and Low-CO₂ Clinker: 16%
- Hydrogen Injection: 5%
- Alternative Fuels: 31%

**Contribution to 2050 Ambition (%)**
- Carbon Capture, Utilization & Storage: 34%
- Concrete Technologies: 18%
- Circular Economy: 4%
- 2030 Cement Levers: 40%

Expected Cement Production Evolution

We are moving to a market where SCM will be blended at the cement plant instead of the ready mix plant.

**Current**
- ASTM C150
  - TY I, TY I/II, TY II/V, TY III

**Short Term 0–2 Years**
- ASTM C595
  - Standard: TY IL Portland Limestone Cement
  - Specialty: TY III

**Long Term 4–10 Years**
- ASTM C595
  - TY IP Pozzolan Cement, TY IS Slag Cement, TY IT Ternary Blends (Pozzolan + LS, Slag + LS, etc.)

Typical Clinker Factors in the U.S.

- 90% - 95% Type I, II, V
- 80% - 86% Type IL
- 70% - 80% Type IP, IS
- 60% - 70% Type IT
Blended Cements –
A hydraulic cement consisting of two or more inorganic constituents (at least one of which is not portland cement or portland cement clinker) which separately or in combination contribute to the strength gaining properties of the cement . . .”

- Materials
  - Limestone
  - GGBF slag/slag cement
  - Fly ash
  - Silica fume
  - Calcined clays
  - Calcined shale
  - Natural pozzolans
  - Alkali Activated Slag
  - LC3
  - Synthetic Limestone
  - Etc.
Type 1L / Portland Limestone Cement (PLC)

A Greener Cement Option

- A blended cement with additional limestone content
  - ASTM C595 / AASHTO M240 allows 5%-15%
  - Most producers use 10%-12% addition rate
- Carbon reduction ~ 7 - 9%
- Designed to perform "equivalent" to Ordinary Portland Cement (OPC)
  - PLC is ground finer
  - Water demand may be slightly higher
  - Early / later strengths should be similar
  - Set time should be similar
  - Color is slightly lighter
- Suitable for all applications

https://www.greencement.com

Cement Consumption

Total US

The cement industry has changed more in the last 3 years than the previous 50+ years

- Historically, blended cement Avg ~2%
- In 2022 ~ 23% of Cement sales were blended
- In 2023 ~51% of 2023 Cement Sales were blended
- The vast majority of this is Portland Limestone Cements (PLC aka Type 1L)

Blended Cements

- Blended cements are cements where part of the clinker is substituted with other materials.
  - Granulated slag
  - Fly ash
  - Uncalcined limestone
  - Calcined clay
  - Etc.

- Blended hydraulic cements must conform to the requirements of ASTM C595 (or AASHTO M 240)
  - Type IL, Portland-limestone cement
  - Type IP, Portland-pozzolan cement
  - Type IS, Portland blast-furnace slag cement
  - Type IT, Ternary blended cement

- Blended cements are used in all aspects of concrete construction in the same manner as portland cements.

Blended Cements are intended to behave similar to OPC mixes with higher levels of SCMs.

ASTM C595 / AASHTO M240 Modifiers

- (No Modifier) – Normal
- (LH) - Low Heat of Hydration
- (MH) - Moderate Heat of Hydration
- (MS) - Moderate Sulfate Resistance
- (HS) - High Sulfate Resistance
- (A) - Air Entraining

(Y XX) – Addition Type & % Added

Example
- Type IT (S25)(P10)(MS)A
  - An air-entraining cement with moderate sulfate resistance containing 10% pozzolan and 25% slag

Changes in CO₂ emissions from producing a blended cement.
The example is for CEM IV B 32.5 cement with 35% granulated slag (Ecoserve Network, 2004a).

The difference between concrete with blended cements & concrete with SCM’s is where is the SCM is added.
What Blended Cement is Made of Depends on the Source of Materials
Coal Ash (Current Production)

As coal power is phased-out, fly ash availability will be constrained

Fly ash supply is limited in the West

Sources:
Bluefield Research: https://www.bluefieldresearch.com/research/coal-ash-ponds/

Approximately 1,227 coal ash ponds
417 Plants.
More than 95% of coal ash storage capacity is located in 20 U.S. states.

Sources:
Earthjustice https://earthjustice.org/feature/coal-ash-contaminated-sites-map
Bluefield Research: https://www.bluefieldresearch.com/research/coal-ash-ponds/
What Blended Cement is Made of Depends on the Source of Materials

**Slag**

The last remaining blast furnaces are located in the Great Lakes region.

Maximum trucking distance can limit the area in which this SCM can be used.

Theoretically, imports could be used in plants near the coasts, but probably no real CO2 reduction vs SCM in concrete.


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**Natural Pozzolan Sources**

- ~10 NP Production Facilities
- ~10 more deposits in various phases of development
- Production ~ 1.5M tons & growing

Source: Natural Pozzolans - Joseph Thomas, NPA, Spring 2023 NCC Meeting
What Blended Cement is Made of Depends on the Source of Materials
Kaolinite (source for Calcined Clays)

Calcined clay – or metakaolin – is produced by heating a source of kaolinite to between 650°C and 750°C.

The need to activate metakaolin through heating has made the production more costly than other SCMs

Source:

US State DOT Acceptance of ASTM C595 / AASHTO M240 Cements
Type IP, IS & IT Cements (VERY Preliminary and Subject to Change)

Most states accept IP & IS cements, and some accept IT cements. However, the limits, applications, and other criteria vary WIDELY and could be a hurdle to usage.
27 distinct common cement products grouped into the following categories:

- CEM I Portland cement (>95% clinker)
- CEM II Portland-composite cement (65-94% clinker)
- CEM III Blastfurnace cement (5-64% clinker)
- CEM IV Pozzolanic cement (45-89% clinker)
- CEM V Composite cement (20-64% clinker)

While Blended Cements will be new to the US, there is a successful history with them elsewhere.
Blended Cements – General Properties

- Compared to portland cements, often blended cements are believed to have
  - lower early strength
  - higher ultimate strength
  - lower heat of hydration
  - Strength at 28 days comparable

- Blended Cements are NOT a 1:1 replacement for straight cement mix
  - Performance will vary and will most likely be similar to a PLC with different amounts of SCMs
  - Compared to SCM replacement at the RM Plant, should have better consistency, optimum fineness, better chemical control, durability
  - Limits on flexibility, and reduced early strength

- Same as now, when new materials are introduced, lab testing, trail batches and Field mockups are recommended

Blended Cements – Strength Gain

Compared to OPC, blended cements typically have lower early strength, higher ultimate strength, and comparable 28-day strength

Sources:
PCA RD112, Supplementary Cementing Materials for Use in Blended Cements
PCA RD102, Evaluation of the Long-Term Properties of Concrete
Compared to OPC, blended cements typically have lower early strength, higher ultimate strength, and comparable 28-day strength.

Important to remember, just as with normal OPC, there will be variability in results.
With a few exceptions, the final setting times for all cements range from about 180 to about 280 minutes.

Sources:
PCA R&D SN2879, U.S. and Canadian Cement Characteristics, 2004
PCA R&D SN3284, Chemical and Physical Characteristics of US Hydraulic Cements: 2014
As More Type 1L / PLC has been Sold, Issues have Started to Rise

- All the problems that existed prior to PLC with OPC still exist (testing, water addition, poor QC, lack of curing, ...)
  - Last big thing to change is the first thing to get blamed for problems
- Reported Performance Differences
  - Water demand / strength; Less or later Bleed / finishing; Increased drying shrinkage; Increased cracking potential; Certain admixtures less efficient; Switching between PLCs sources
- Timing of transition
  - Coordinating the customer, cement plant, logistics
  - Acceptance of specifiers, owners, contractors
  - Pushed limestone content too high before mill optimization → low strengths
  - Short or intermittent production runs → higher variability

So, the Question becomes “How do we avoid these issues as we move forward?”

CEMEX Plan for Improved Implementation

Communication

- Coordination and communication with customers about plans
  - When could / will we start producing or importing PLCs and Blended Cements
  - Sharing internal test data
  - Providing contractors and specifiers with help and education
  - Encourage Testing and Mockups when needed
Impact on Setting Time and Early Strength

- Concrete set time with Type IL is generally +/- 15% compared to its Type II counterpart. Depends on:
  - Cement plant/finish mills/transitioning stage
  - Percent limestone
  - % 325 / Blaine
  - Concrete mixture design
- Concrete initial set time may be similar but heat generation and strength in the first 24 hours will typically be lower with Type IL.
- Concrete strengths with Type IL should be comparable in most cases by 3 to 7 days, and out to 28 days.

My semi-educated guess is that Blended Cements will behave similarly to IL with 20% Natural Pozzolans

Concrete with Ty-IL may be more Sensitive to Cooler Weather & SCM’s

Less clinker in Type IL cement generates less early heat, which can affect early age strength gain

Source: Information Courtesy of Burnco, & Dana Rotkovich, Operations Manager North Colorado Ready Mix
Concrete with Ty-IL may be more Sensitive to Cooler Weather & SCM's
Compressive Strength (Cure at given Temperature for the first 48 hours)

- Less clinker in Type IL cement generates less early heat.
  - Generally, not an issue in warmer weather.
  - In cooler weather, less heat may potentially be a concern.
- Addition of SCM's further reduces clinker content & early heat development compared to concrete with Type II
  - Once
- Concrete placed for flatwork in cooler weather using Type IL and SCM's may not develop adequate early strength to prevent early age cracking. This may be addressed with:
  - Limit SCM content
  - Accelerators
  - Hot water

Blended cements will probably be similar but admixture & other advancements are being developed

Sources:
Information Courtesy of Burnco, & Dana Rotkovich, Operations Manager
North Colorado Ready Mix

Impact on Bleeding

PLCs generally decrease bleeding
- Degree of impact influenced by fineness and particle size distribution of finished cement
  - Finish mill circuit set up
  - Strength targets
  - Performance enhancing grinding aids
  - Amount of limestone
  - Amount, Rate, and Duration all matter

Can be controlled in concrete
- Water content
- Admixtures
- Aggregates

Pretesting and evaluations are needed to develop robust mix designs to minimize field complaints in flatwork.
CEMEX Plan for Improved Implementation
Testing is Needed

• Testing prior to switching cements minimizes problems
  • OPC from cement plant A to OPC from cement plant B
  • OPC from cement plant A to PLC/Blended Cement from cement plant A
  • PLC/Blended Cement from cement plant A to PLC/Blended Cement from cement plant B

• PLC/Blended Cement are probably similar to OPCs with high SCMs, but...
  • Not every OPC will behave the same as PLC/Blended Cement from the same plant in every application
  • Not every OPC is the same, nor is every PLC/Blended Cement the same

• What Testing and Evaluation
  • TBD: Lab trials, truck trials, trial placements with contractor
  • Will it reach same OPC strength at the same slump or the same water content?
  • Differences in bleed?
  • Side-by-side with control OPC may be needed

Common adjustments for performance

• Nothing – Design with the PLC/Blended Cement
• Increase water content
• Increase water reducer content
• Notification of flat work finishers decrease in bleed
• Others

• Side-by-side with control OPC may be needed
Key Takeaways: How to make this Work

When using Blended cements, need to think of comparisons of OPC/PLC with SCMs

- Blended cements are hydraulic cements used like portland cements
- Specifications define the requirements and optional properties
- Performance similar to portland cements

Testing and Trial Batches are a must (no 1:1 Replacements)

- Admixtures will play an increasing vital role
- Placing, finishing, and other construction requirements may (will) need to be changed and updated
- Concrete may be more sensitive to changing weather conditions
- New “rules of thumbs” will have to be developed

Switching Cement Sources could become much more difficult

- The blended cement developed by 1 cement producer may not (probably not) be the same as another producer
- The concrete produced by 1 RM concrete producer may not (probably not) be the same as another producer

Communication and Partnership are Critical:

- Specifications requirements must meet both Agency and Industry needs

Q&A

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