More Sustainable Concrete Pavements

Peter Taylor

Setting the Stage

What do humans need:
• Sustenance
• Shelter
• Help
• Hope

Imagine a world without infrastructure:
• Transportation
• Energy
• Expertise

Transportation effects are non-trivial
Setting the Stage

• Imagine a world without concrete
  • Buildings
  • Services
  • Transportation

So let's keep building!
  • But…

We use a lot of concrete
  • Concrete impacts the environment
  • Changes in environment affects infrastructure needs

The conundrum then is: how do we deliver/maintain the infrastructure without hurting the planet?

https://architecture2030.org/ipcc_analysis/
Setting the Stage

A Balancing Act

- Economics still rule
- It’s more than carbon, but…

Where Does the Carbon Come From

- Heat! (about 40%)
  - Cement ingredients heated to ~1400ºC
  - Heat exchangers improve efficiency
  - Alternative fuels
- Chemistry (the rest)
  - CaCO3 → CaO + CO2
  - CaO + other stuff → portland cement
  - Can we use alternative calcium sources?
- Most of the CO2 footprint is tied to the cementitious system

Materials

What can we do?

- Use less concrete
- Use less binder in the concrete
- Use less clinker in the binder

Use Less Concrete in the Structure

- More efficient designs
  - Beware of rules of thumb, and cut-and-paste
  - ME-Design procedure
- Avoid replacing it
  - Longer lasting
  - Use existing equity of older pavements (overlays)
Use Less Binder in the Concrete

- Cementitious binder is about 9-15% by mass of concrete
- Many specifications call out a minimum
  - That may be more than needed

Use Less Binder in the Concrete

- Minimum required is defined by
  - Enough paste to fill the gaps between the aggregate, plus a bit
  - Aggregate gradation
  - Workability
- Excess can be deleterious
- Performance Engineered Mixtures
  - Some states are reporting cutting binder contents by 30%

Use Less Cement in the Binder

- Supplementary cementitious materials
  - Enhance performance
  - Increase longevity
  - Reduce disposal headaches
  - Ternary combinations
  - What about their carbon footprint?

Use Less Cement in the Binder

- Supplementary cementitious materials
  - Availability locally?
  - Harvested fly ash
Use Less Cement in the Binder

- Other SCMs
  - Recycled Ground Glass, ASTM C1866
  - Locally processed waste products
- Cost of testing compared with value of product

Use Less Cement in the Binder

- Portland Limestone Cements
  - Up to 15% ground limestone
  - Similar performance
- Becoming the norm

Reduce Carbon Footprint of Cement

- PCA has a plan…

Use Low-Carbon Cements

- Geopolymer cements / Activated fly ashes
- Calcium sulfo-alumina-cements
- Belite cements
- Other chemistries
- Balancing availability, cost, constructability and longevity…
**Use Low-Carbon Cements**

- Test sections being planned at MNRoad
  - Assess CO₂ savings
  - Measure performance under traffic
  - 16 sections
    - Control and optimized mixtures
    - Reclaimed fly ashes
    - Geopolymers
    - Carbon injection
    - Innovative SCMs

**Other Actions**

- Recycled Concrete
  - Reduces need for virgin materials
  - Eliminates disposal needs
  - Foundation or in the concrete?
    - Depends on quality needs
  - About 140 Million Tons recycled annually

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**Recycled Concrete Aggregate**

Technical products developed:
- How to engineer RCA applications
- Use RCA in most advantageous way

Coming soon
- Construction by-products
- RCA in pavement mixtures
- Industrial by-products

**Put the Carbon Back!**

Natural carbonation
- Slow
- Dependent on environment
- Can compromise steel protection
- Can be accelerated with grinding
Put the Carbon Back!

- Inject carbon dioxide into concrete in the mixer
- CO₂ is mineralized then converts to solid CaCO₃
- Reported to improve permeability

Measurement

- Life-cycle assessment (LCA)

Use Phase

- Fuel consumption
- Care and keeping

Measurement

- EPDs are coming
Construction

- Haul distance
- Delays
  - Traffic
  - Safety
- Disturbance
  - Noise
  - Dust
  - Access

Other Factors

- Resilience
- Albedo (heat island)
- Lighting
- TiO2

So

- This is not new

So

- Change is inevitable
- Change has happened
- Incremental change will help - Is that enough?
- What next?
Increasing Concrete Pavement Sustainability while Improving Durability: Colorado’s Experience

Angela Folkestad, P.E.
CO/WY Chapter – American Concrete Pavement Association

Stages of Opportunities for Reducing GHG Emissions & Increasing Sustainability

• Before Construction
• During Construction
• After Construction

Optimizing Concrete: Pushing Performance

Reducing Emissions Before & During Construction

• Pavement Design
• Materials Selection and Mixture Design Specifications
  • Aggregates
    • Multiple gradations
    • Recycled concrete
  • Cementitious Materials
    • Portland Limestone Cement (PLC), or Type IL
    • Supplementary cementitious materials

Most common target of discussion based on cement’s reputation as a large producer of greenhouse gas emissions
### Optimized Gradations

- **Single-sized**
- **Partly graded**
- **Wet-graded**

### CDOT Concrete Pavement Minimum Cementitious Contents

- **Minimum Fly Ash**
- **Minimum Cement**

- **20% fly ash addition allowed**
- **20% fly ash addition required**
- **Minimum substitution**
- **20% fly ash required**

- **Minimum cementitious eliminated October 2019**

### Portland Limestone Cement (PLC) – AKA Type IL

- **Blended cement with higher limestone content & average reduction in carbon footprint of 10%**
  - [www.greenercement.com](http://www.greenercement.com)

- **Portland cement can contain up to 5% limestone along with the clinker**
- **Portland-limestone cement can contain from 5% to 15% limestone along with the clinker.**

- **If all cement used in the U.S. in 2019 had been converted to PLC (Type IL), it would have reduced CO₂ emissions by 8.1 million metric tons, which the U.S. EPA says is the equivalent of taking 1.75 million cars off the road for an entire year.**
Why Portland Limestone Cement (PLC)?

- Producing PLC reduces amount of cement clinker needed per ton
  - Reduces carbon footprint of cement/concrete
  - Every 10 tons of PLC produced reduces CO₂ emissions by approximately 1 ton compared to OPC
  - Reduces the amount of energy required per ton of cement
- Producing PLC increases cement plant capacity
  - Varies from plant to plant depending on clinker capacity vs. mill capacity
- Designed to perform the same as Ordinary Portland Cement (OPC)
  - Water demand may be slightly higher due to fineness
  - Early strengths may be higher
  - Set time should be equal
  - Color is slightly lighter

CDOT Specifications – PLC allowed since 2008

- ASTM C1157 GU used initially
- ASTM C595 Type IL introduced in fall 2014

Documenting PLC Testing, Use & Performance

“Using portland limestone cements for over 10 years allows Colorado to reduce greenhouse gas emissions in the construction of concrete pavements with no compromise in quality and long-term performance.”

Eric Prieve, CDOT Concrete & Physical Properties Engineer

1st CDOT PLC Project @ 11 years old (2019)
1,500 Lane-Miles of Concrete Pavement w/ PLC

US 36 Denver to Boulder

C-470 – SW Denver

Pena Blvd – Access to DEN

On-Site Aggregate Mining & Concrete Batching

Dramatically reduces truck trips & related emissions

Onsite Concrete Batch Plant & Recycled Concrete Aggregate (RCA)

Recycled Concrete Aggregate (RCA)
### Recycled Aggregate Base

- Optimized gradations – reduces paste content (and cement)
- Recycled concrete
  - Aggregate in new concrete
  - Base material
- Allow for Portland Limestone Cement (PLC) – aka Type IL
- Require use of supplementary cementitious materials
  - Fly ash – byproduct of coal fired power production
  - Slag cement – byproduct of steel production
- Include permeability testing

### Concrete Mix Specifications: Use Performance Engineered Mixtures (PEM)

- Optimized gradations – reduces paste content (and cement)
- Recycled concrete
- Aggregate in new concrete
- Base material
- Allow for Portland Limestone Cement (PLC) – aka Type IL
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### Specification References

  - Section 412 – Concrete Pavement
  - Section 601 – Structural Concrete (Class P is for Pavement)

  - Item 30 – Portland Cement Concrete Materials

### Environmental Product Declarations (EPDs)

#### Why are we talking about them in CO?

- HB 21-1303 signed & incorporated into C.R.S. 24-92 in July ’21
  - Section 24-92-117 – Office of the State Architect
  - Section 24-92-118 – Colorado Department of Transportation
- Requires CDOT to begin collecting EPDs per ISO 14025 on eligible projects for certain eligible materials
- CDOT must use collected EPDs to develop a policy establishing maximum Greenhouse Gas emissions for each eligible material
- CDOT working out details of exceptions to EPD submittal - will be outlined in the final “Buy Clean Colorado” Specification.
**HB 21-1303 Timeline**

- **July 2022**: EPD Collection
  - Winning bidder to submit EPDs for eligible materials on eligible projects
- **July 2025**: EPD Requirements
  - Winning bidder to submit EPDs for eligible materials as established by policy
- **January 2027**: Review & Adjust Policy
  - CDOT to review and adjust policy every 4 years

**EPDs Measure Cradle to Gate Impacts**

- Substantial portion of impacts are not captured through EPDs

**Reducing Gate to Grave Impacts**

- **Pavement preservation/restoration**
  - Extend life of pavement
  - Minimize disruption & maximize resource efficiency w/ negligible resource extraction
  - Utilize numerous techniques including diamond grinding

- **Concrete overlays as preservation**
  - Resource efficient & eliminates disposal
  - Cost effective & quick to construct
  - Long life
Thank You!

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