Sustainable Concrete Construction

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Setting the Stage

Imagine a world without infrastructure:
- Transportation
- Sustenance
- Shelter
- Expertise
- Energy

• Transportation effects are non-trivial

• Imagine a world without concrete
  - Buildings
  - Services
  - Transportation
So let's keep building!

- But…

Why Sustainability?

- 30 billion tons of concrete is used each year worldwide
- ~½ ton CO₂ per person per year

We need a lot of concrete so the impact is high

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

- Economics still rule
- But carbon…

https://architecture2030.org/ipcc_analysis/
Where Does the Carbon Come From

- Heating the kiln
  - Can and has been reduced
- Decomposing limestone rock
  - Has to be balanced
- Traffic
  - Can be reduced

How?

- What can we do to reduce impact?
  - Use less concrete
  - Use less binder in the concrete
  - Use less clinker in the binder
  - Reduce construction impacts
  - Reduce user impacts

Use Less Concrete in the Structure

- Avoid replacing it
  - Longer lasting
  - Use existing equity of older pavements (overlays)
- More efficient designs
  - Beware of rules of thumb, and cut-and-paste
  - Appropriate construction systems

Use Less Binder in the Concrete

- Many specifications call for more than needed

<table>
<thead>
<tr>
<th>Component</th>
<th>Conventional</th>
<th>Optimized</th>
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Use Less Cement in the Binder

- Supplementary cementitious materials
  - Enhance performance
  - Increase longevity
  - Reduce disposal headaches
- Ternary combinations
- Harvested fly ash

Use Less Cement in the Binder

- Other SCMs
  - Recycled Ground Glass, ASTM C1866
  - Locally processed waste products ASTM C 1709
    - LC3 cement

Use Less Cement in the Binder

- Portland Limestone Cements
  - Up to 15% ground limestone
  - Similar performance
    - Becoming the norm
- Non-portland cements
  - Geopolymer cements / Activated fly ashes
  - Calcium sulfo-alumina-cements

Use Low-Carbon Cements

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

Other Factors
- Recycled Concrete Aggregate
- Albedo (heat island)
- Lighting (& light pollution)
- TiO₂
- Resilience

Construction
- Haul distance
- Disturbance
  - Noise
  - Dust
  - Access
- Delays
  - Traffic
  - Safety
Use Phase

• Fuel consumption
• Care and keeping

End-of-Life
19%

Use 15%

Maintenance & Rehabilitation 7%

Breakdown of lifecycle greenhouse gas emissions for a pavement in Missouri

*Other carbonation & lighting

Measurement

• Life-cycle assessment (LCA)

https://www.epa.gov/greenvehicles/electric-vehicle-myths#Myth5

• Ask for what is needed, and no more
  • Understand what makes concrete "good"
  • Specify the critical properties and test for them
  • Prepare the mixtures to meet those specifications

Measurement

• EPDs are coming

NRMCA
In Summary

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In Summary

- This is not new

Where next?

- Keep encouraging the community to adopt change

- Keep working on:
  - Alternative materials
  - Developing the tools to quantify concrete in the field
  - Building long lasting / low impact pavements

So

- Some things we can change now
  - Make better concrete
  - Make better pavements

- Others will take time

The Difficult We Do Immediately. The Impossible Takes a Little Longer