Sustainable Concrete Construction

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Setting the Stage

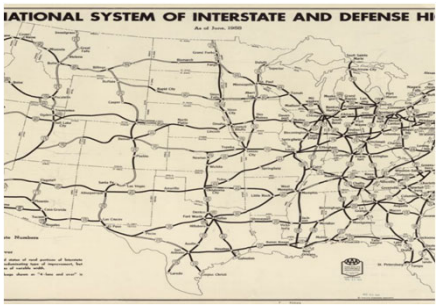
Imagine a world without infrastructure:

- Transportation
  - Sustenance
  - Shelter
  - Expertise
- Energy

Setting the Stage

- Transportation effects are non-trivial

Python Maps



Library of Congress

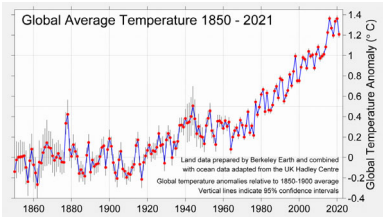
Setting the Stage

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

Setting the Stage

So lets keep building!

- But…

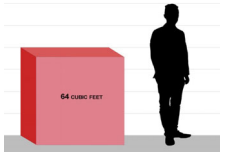


Berkeley Earth

Why Sustainability?

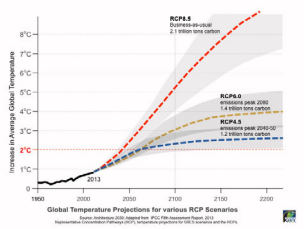
- 30 billion tons of concrete is used each year worldwide
- ~½ ton CO_2 per person per year

We need a lot of concrete
so the impact is high



Setting the Stage

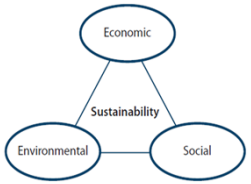
The conundrum then is: how do we deliver/maintain the infrastructure without hurting the planet?



https://architecture2030.org/ipcc_analysis/

Setting the Stage

- Economics still rule
- But carbon…



BBC

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

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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

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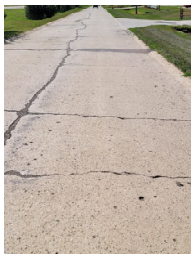
Use Less Concrete in the Structure

- 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



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Use Less Binder in the Concrete

- Many specifications call for more than needed

	Conventional	Optimized
Cement	400	351
SCM 1	170	150
SCM 2	0	0
Coarse Agg	457	662
Fine Agg	1171	1303
Intermediate 1	1167	954
Intermediate 2	244	254
Water	228	200
Air	7.0	7.0
Total	3837	3874
Cementitious	570	501
vp/vv	208	180
w/cm	0.40	0.40
% SCM 1	30	30

	Conventional	Optimized
Slump	2.0	2.0
HRWRA	2.0	2.3
Air content	6.8	7.0
Box	1 - 0	1 - 0
Initial set	6:27	6:12
Strength at 7	3,340	3,650

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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

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Use Less Cement in the Binder

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

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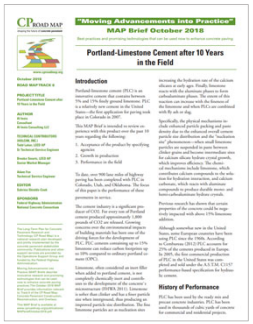
Use Less Cement in the Binder

- 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


"Moving Advancements into Practice"
MAP Brief October 2016
Portland-Limestone Cement after 10 Years in the Field
Introduction
History of Performance

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Use Low-Carbon Cements

- Test sections built at MNRoad
  - Assess CO_2 savings
  - Measure performance under traffic
  - 16 sections
    - Control and optimized mixtures
    - Reclaimed fly ashes
    - Carbon injection
    - Innovative SCMs

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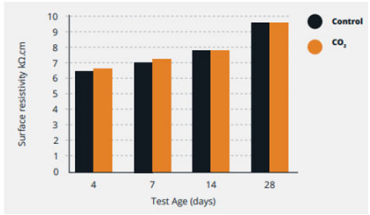
Put the Carbon Back!

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
- CO_2 is mineralized then converts to solid $CaCO_3$
- Reported to improve permeability



CarbonCure

Other Factors

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

- Resilience

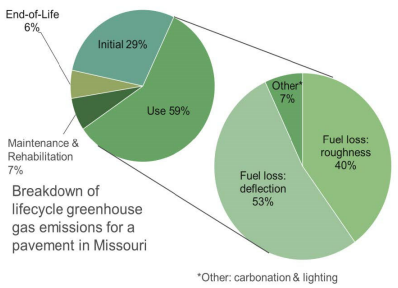
NOAA

Construction

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

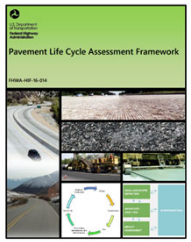
Use Phase

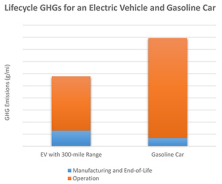
- Fuel consumption
- Care and keeping



Measurement

- Life-cycle assessment (LCA)





Measurement

- 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

Table 8a. Summary Results (A1-A3): 3001-4000 psi (20.7-27.6 MPa) RMC product mix design, per cubic meter

		Minimum	Maximum	3001-4000-00-FA/SL	3001-4000-20-FA	3001-4000-30-FA	3001-4000-40-FA	3001-4000-30-SL	3001-4000-40-SL	3001-4000-50-SL	6001-8000-50-FA/SL
Core Mandatory Impact Indicators											
GWP	kg CO_2e	261.19	426.75	426.75	365.48	332.37	297.41	327.67	294.65	261.62	261.19
ODP	kg CFC11e	7.84E-06	1.11E-05	1.11E-05	9.56E-06	8.73E-06	7.84E-06	1.01E-05	9.75E-06	9.41E-06	8.49E-06
AP	kg SO_2e	0.99	1.33	1.33	1.17	1.08	0.99	1.28	1.26	1.25	1.12
EP	kg Ne	0.37	0.55	0.55	0.48	0.44	0.40	0.45	0.41	0.38	0.37
POCP	kg O_3e	21.38	28.22	28.22	24.98	23.23	21.38	25.58	24.70	23.82	22.20
ADPf	MJ, NCV	1,522.19	2,229.70	2,229.70	1,921.20	1,754.51	1,578.49	1,850.63	1,724.28	1,597.92	1,522.19
ADPe	kg Sbe	2.44E-04	3.69E-04	3.69E-04	3.25E-04	3.02E-04	2.77E-04	2.94E-04	2.69E-04	2.44E-04	2.46E-04
FFD	MJ Surplus	143.16	180.58	180.58	162.85	153.28	143.16	172.58	169.91	167.24	154.43

In Summary

	Measurable	Phase	Impact	Who	Side effect	Cost	When
Efficient designs	Yes	Construction	Point of delivery	Agencies	None	Reduced	Now
Reduce cement content	EPD	Construction	Point of delivery	All	None	Reduced	Now
PLC	EPD	Construction	Point of delivery	All	None	Reduced	Now
Cement footprint	EPD	Construction	Point of delivery	Cement	None	Reduced	Later
Increased SCM	EPD	Construction	Point of delivery	All	None	Reduced	Now
Carbon injection	??	Construction	Point of delivery	All	None	-	Now
Non-portland	EPD	Construction	Point of delivery	All	Cost	Increased	Later
Construction practices	Yes	Construction	Point of delivery	Contractor	None	Reduced	Now
Recycling	Yes	Construction	Point of delivery	All	Reduced disposal	Reduced	Now
Smoothness	Yes	Use phase	Reduces others' footprint	Contractor	Improved safety	Reduced	Now
Albedo	Yes	Use phase	Reduces others' footprint	Agencies	Cooler city	Reduced	Now
Lighting	Yes	Use phase	Reduces others' footprint	Agencies	Improved safety	Reduced	Now
Long life	Yes	Use phase	Later	Agencies	Improved safety	Reduced	Now
Carbonation	Yes	Use phase	Later	All	None	-	Later
Sequestration	Yes	Use phase	Later	All	None	Increased	Later

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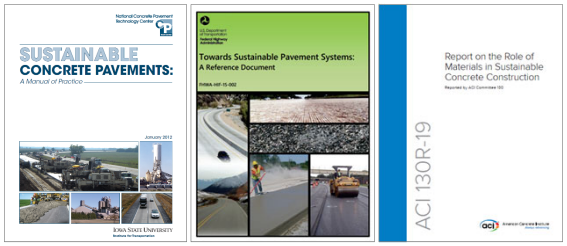
In Summary

- This is not new



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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

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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

28 Strijdom van der Merwe — Charles Alexandre de Calonne, 1794


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