Linking PEM and Sustainability

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Outline

- Why Concrete
- Why Sustainability
- Why PEM
- Putting them all together

Why Concrete?

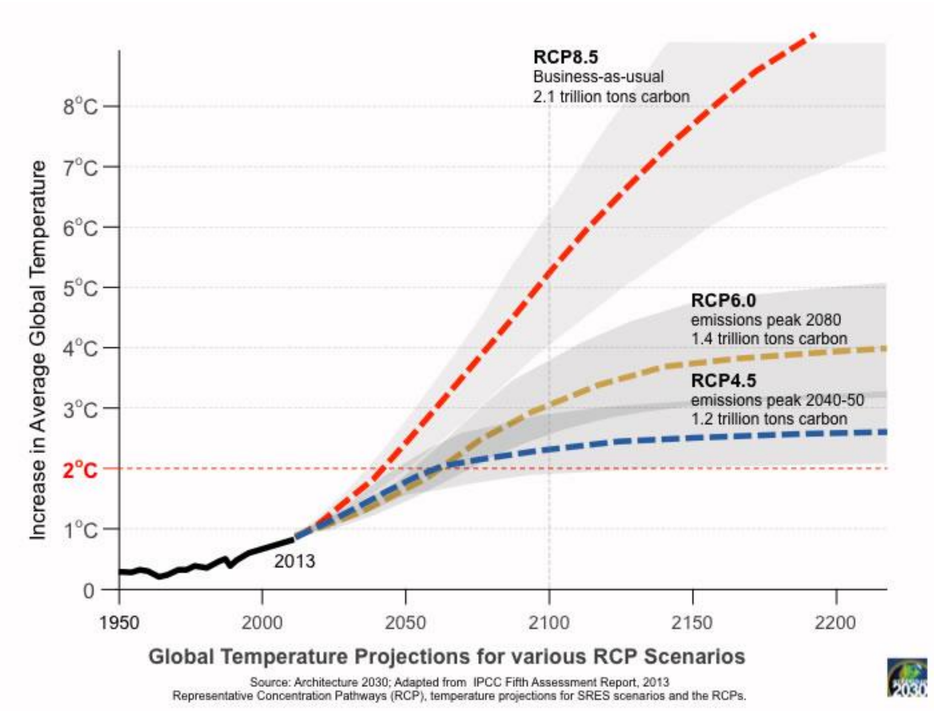
What do we depend on?

- The ability to move
  - Energy
  - Food / Stuff
  - People
  - Water
  - Knowledge
- Shelter

Why Sustainability?

- But…
  - 30 billion tons of concrete is used each year worldwide
  - ~0.5 tons CO_2 per person per year

We need a lot of concrete so the impact is high



https://architecture2030.org/ipcc_analysis/

Why Sustainability?

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

- Economics still rule
- But carbon…
  - Short term
  - Long term

Where Does the Carbon Come From

- Heating the kiln
  - Can be reduced

- Decomposing limestone
  - Has to be balanced

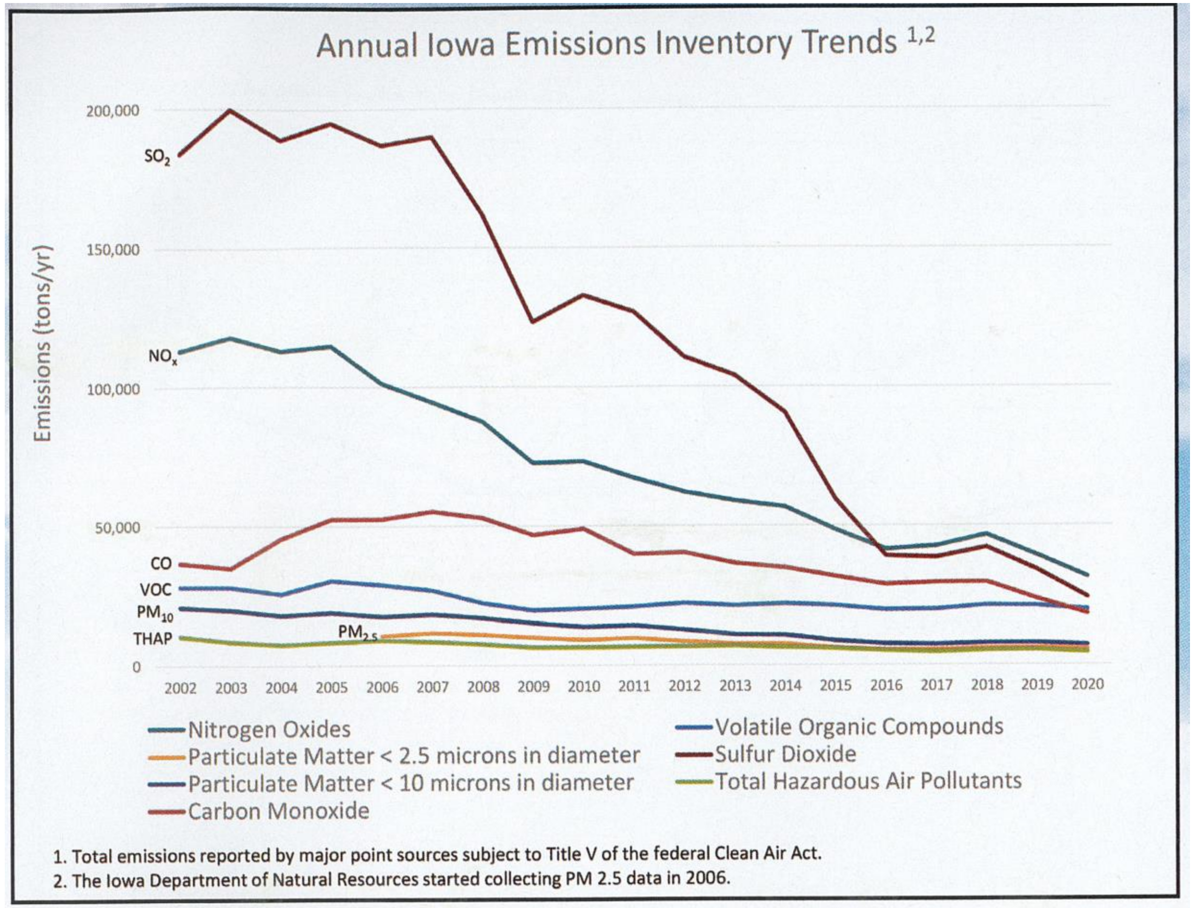
- Traffic
  - Can be reduced

Who Me?

- Cement industry
  - Improve efficiency
- Construction industry
  - Improve efficiency
- Owner agencies
  - Specify / allow reduced carbon systems
  - Aim for longevity
  - Reduce vehicle impacts
- Everyone
  - Carbon sequestration

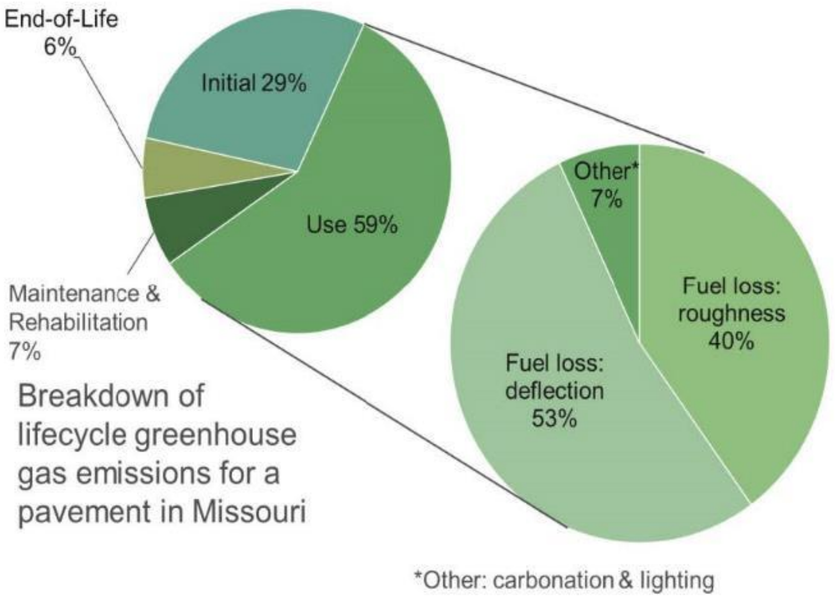
Who Me?

- Change is hard – but possible



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

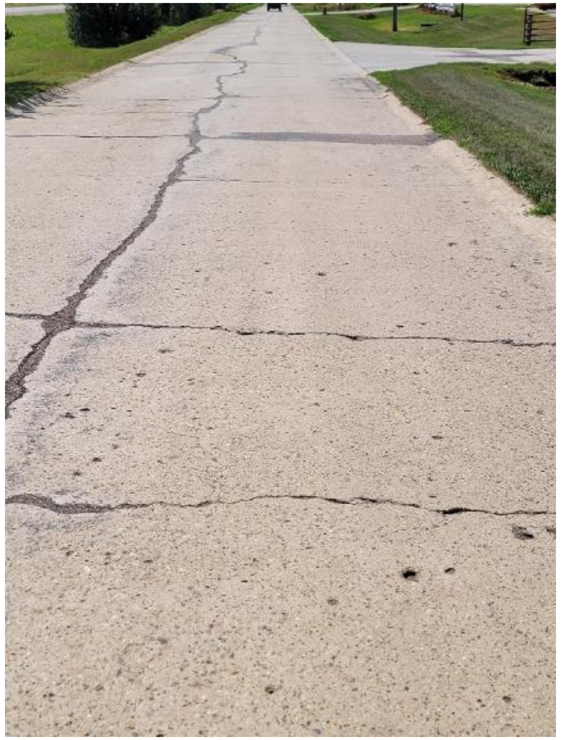


Breakdown of lifecycle greenhouse gas emissions for a pavement in Missouri

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
  - ME-Design procedure
  - Appropriate construction systems



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

Use Less Cement in the Binder

- Supplementary cementitious materials
  - Ternary combinations
  - Harvested fly ash
- Other SCMs
  - Recycled Ground Glass, ASTM C1866
  - Locally processed waste products ASTM C 1709
- Portland Limestone Cements
- LC3
- Non-portland cements

Recycled Concrete Aggregate

- Reduces need for virgin materials
- Eliminates disposal needs

Tech Brief

U.S. Department of Transportation
Federal Highway Administration

SUMMARY AND DISCLAIMERS

The purpose of this Tech Brief is to describe the use of recycled concrete aggregate (RCA) in concrete paving mixtures and identify considerations for its use in highway infrastructure. The document is intended for highway agency and contractor engineers.

The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. This document is intended only to provide clarity to the public regarding existing requirements under the law or agency policies. However, compliance with applicable statutes or regulations cited in this document is required.

American Concrete Institute (ACI) publications, ASTM International, and American Association of State Highway and Transportation Officials (AASHTO) standards are private, voluntary standards that are not required under Federal law. These standards, however, are commonly cited in Federal and State construction contracts and may be enforceable when included as part of the contract.

ADVANCING CONCRETE PAVEMENT TECHNOLOGY SOLUTIONS

USE OF RECYCLED CONCRETE AGGREGATE IN CONCRETE PAVING MIXTURES

INTRODUCTION

Recycled concrete aggregate (RCA) is produced by removing, crushing, and processing hardened concrete. It can be substituted for virgin aggregate in a variety of both bound and unbound uses. Concrete pavement is an excellent source of RCA, because it is generally comprised of high-quality source materials that have previously met state agency specifications.

As virgin aggregate sources and landfill space become limited, use of RCA is becoming increasingly attractive for both environmental and economic reasons (Cackler 2018). While RCA is often utilized in unbound applications, RCA has also been successfully used in new concrete paving mixtures in both laboratory studies and in new pavement construction projects.

Over the past several decades, more than 100 pavement projects have been constructed in the United States using RCA as either a full or partial replacement for coarse aggregate, fine aggregate, or both in concrete paving mixtures (Snyder et al. 1994, Reza and Wilde 2017). Most of these pavements have exhibited satisfactory performance over several decades, and a number of these pavements are still in service today.

In addition, several projects have served to identify limitations with use of RCA and have guided advancements in design and construction processes to improve performance. Overall, when RCA is properly evaluated and considered in mixture design and proportioning, RCA concrete has been found to provide durable performance with accompanying sustainability benefits (Reza and Wilde 2017).

The fundamental principles guiding design and batching of a durable RCA mixture that meets the agency's specifications do not differ from those utilized for conventional concrete mixtures. However, some additional considerations may be needed to ensure suitable performance, and differences in RCA and RCA concrete properties should be considered during the mixture design and development processes. The performance of a pavement should not be compromised when aiming to improve sustainability (FHWA 2007).

This Tech Brief provides information about the effective use of RCA in new concrete mixtures, including characterization of RCA, the expected impacts of RCA on concrete properties and durability performance, and current procedures for proportioning concrete pavement mixtures using RCA. After that, this Tech Brief presents information about pavement design using RCA, along with considerations for RCA production and use. Finally, this Tech Brief briefly describes example projects that illustrate the successful use of RCA in new concrete pavements.

CURRENT USE OF RCA IN CONCRETE MIXTURES

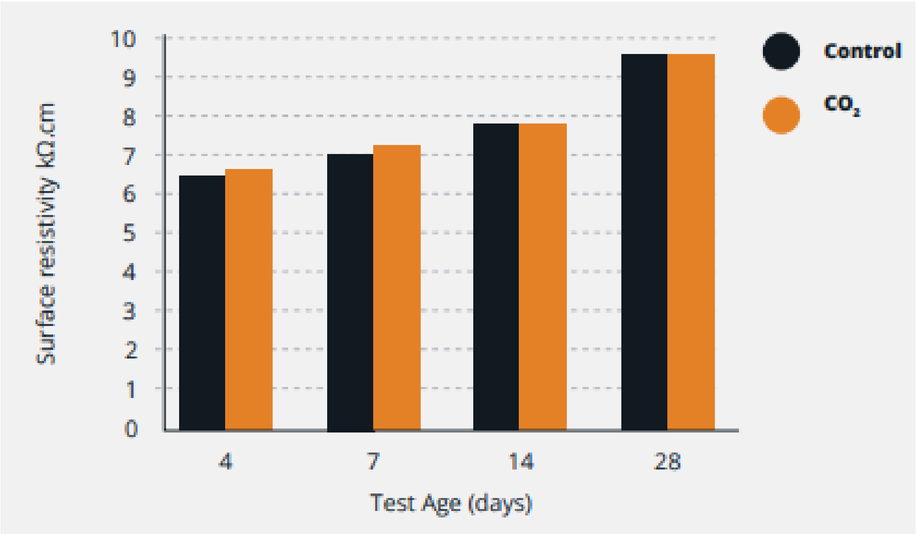
In 2016, a two-part benchmarking survey on the use of RCA was conducted (Cackler 2018). Information regarding the current use of RCA, as well as barriers and challenges to increased use, was solicited from state highway agencies (SHAs) and industry stakeholders. Findings indicated that production of RCA was common on most projects when existing concrete pavement was removed, and opportunities existed to use larger volumes of RCA.

Put the Carbon Back

Natural carbonation

- Slow
- Dependent on environment
- Can compromise steel protection

- Inject carbon dioxide into concrete in the mixer
  - CO_2 is mineralized
  - Reported to improve permeability



Other Factors

- Reduced fuel consumption
  - Higher stiffness
  - Better smoothness
  - Fewer closures

Other Factors

- Resilience
- Albedo (heat island)
- Lighting (& light pollution)

Why PEM?

- A program to develop a better specification for concrete mixtures
  - Understand what makes concrete "good"
  - Specify the critical properties and test for them
  - Prepare the mixtures to meet those specifications
- Ask for what is needed, and no more

How do we know it is good?

- Set the recipe
- Watch the process
- Poke it occasionally
- Break a sample
- Wait and see when it dies

- Trust me…

- Or measure things

Require the things that matter

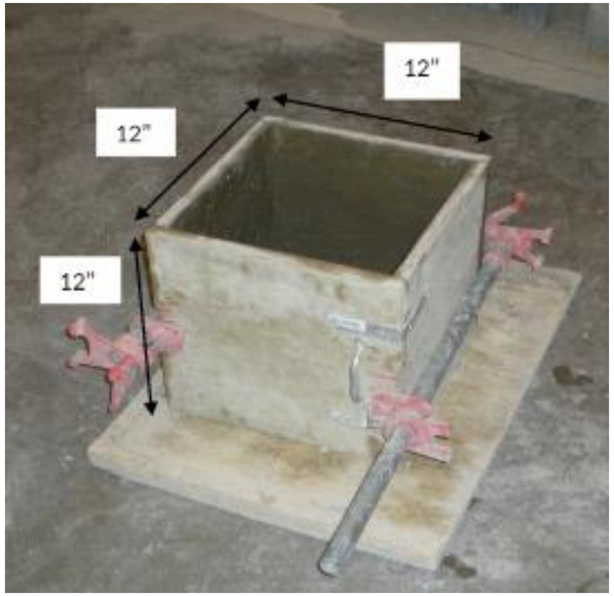
- Transport properties (everywhere)
- Aggregate stability (everywhere)
- Strength (everywhere)
- Cold weather resistance (cold locations)
- Shrinkage (dry locations)

- Workability (everywhere)

Workability

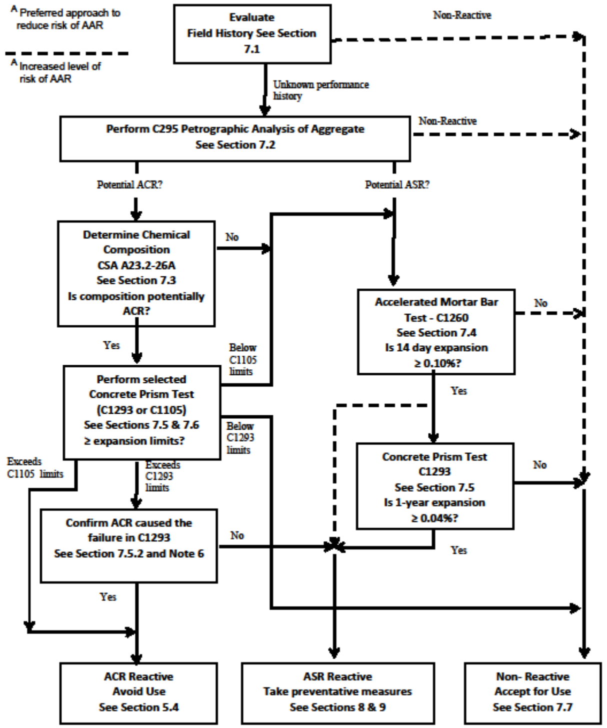
- Not too wet
- Not too dry

- Prequalification



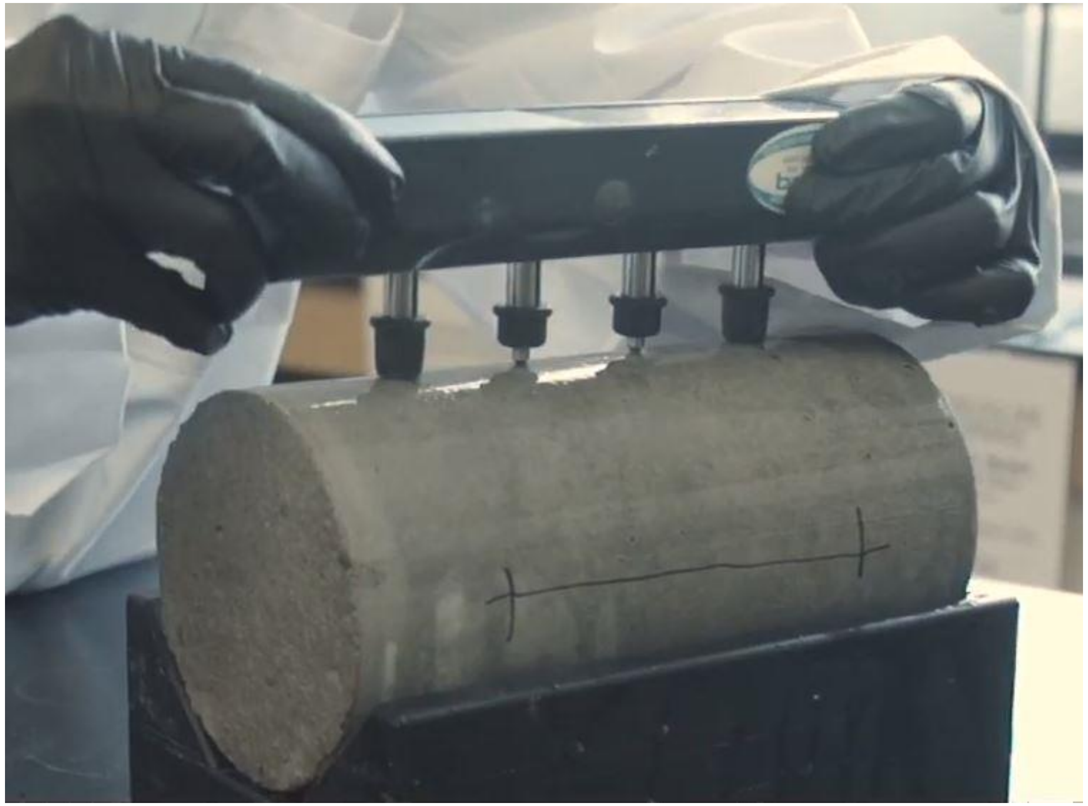
Aggregate Stability

- If aggregates expand = damage
  - Alkali silica reaction
  - D-Cracking
- Follow published guidance
- Prequalification



Transport properties (permeability)

- Keep water out = longer life
- Resistivity
- Prequalification
- QC
- Acceptance



Cold Weather

- Freeze-thaw
  - Saturation
  - Entrained air
- De-icing salts
  - Sufficient SCM

- Prequalification
- QC
- Acceptance

Shrinkage

- Influences cracking risk
- Controls warping
- Takes time

- Paste content (read the batch sheet)

Strength

- Strong enough to carry loads
  - Cylinders
  - Beams
  - Maturity

- Prequalification
- QC
- Acceptance

Achieving design goals?

- AASHTO R101 avoids micromanaging proportions
- Tools are available to help contractors optimize mixtures

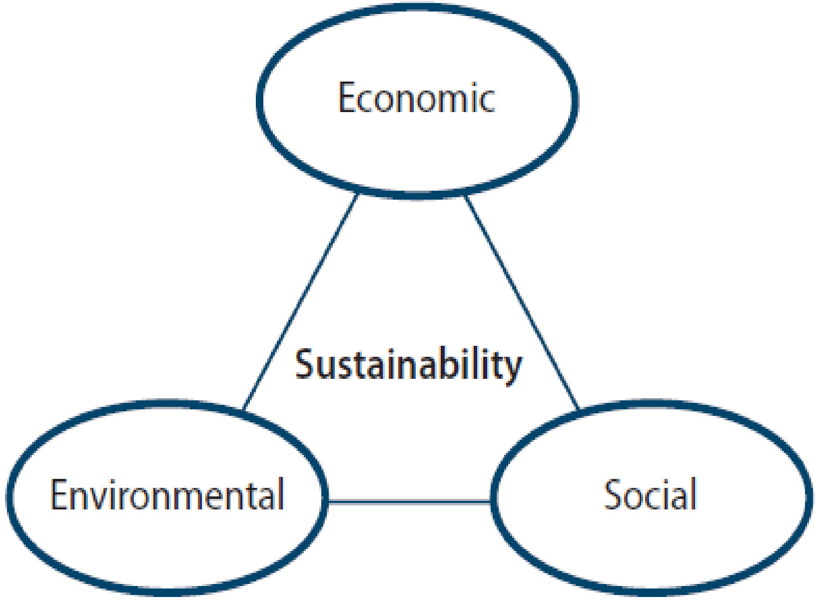
		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	Type, gradation	✓✓	-	-	-	-	✓✓
Paste quality	Air, w/cm, SCM type and dose	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	Vp/Vv	✓	-	-	-	✓✓	-

Tying it all together

- Concrete that delivers what is needed
  - Long life
  - Minimum impact
    - At time of construction
      - Increased SCMs, reduced cement
    - In the use phase
      - Reduced fuel usage

- What about cost?
  - Reduced

Equals Sustainability



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	EPD	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

So

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

- Others will take time
  - Sequestration

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

Charles Alexandre de Calonne, 1794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