Linking PEM and Sustainability

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Outline

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

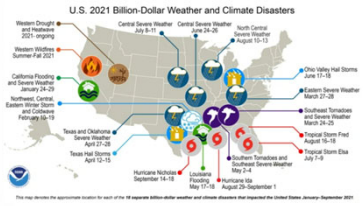
Image: ACPA

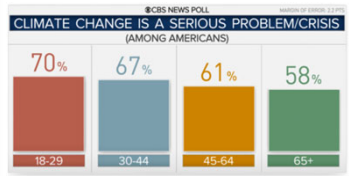
SUSTAINABILTITY…?

- Economic growth and resilience
- Affordability
- Energy security
- Process efficiency
- Outputs of desired products

- Water quality and
- Air quality
- Greenhouse gas emissions
- Biodiversity and

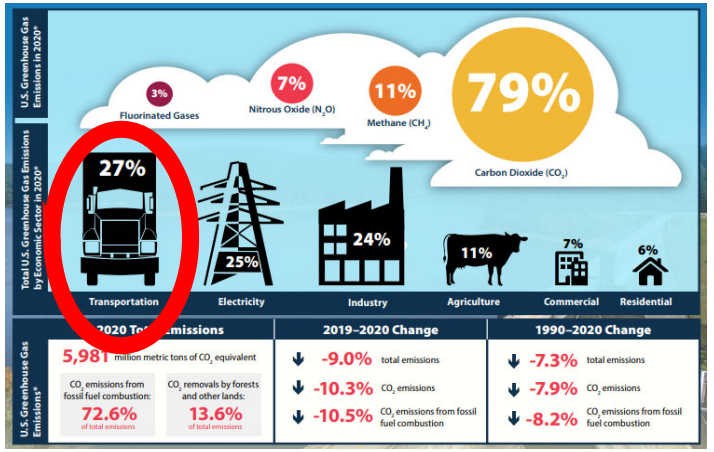
- Jobs and workforce development
- Health and well-being
- Food security
- Social acceptability





Figures: DOE, NOAA, CBS

CONTEXT



Source: EPA

CONCRETE SUSTAINABILTITY…?

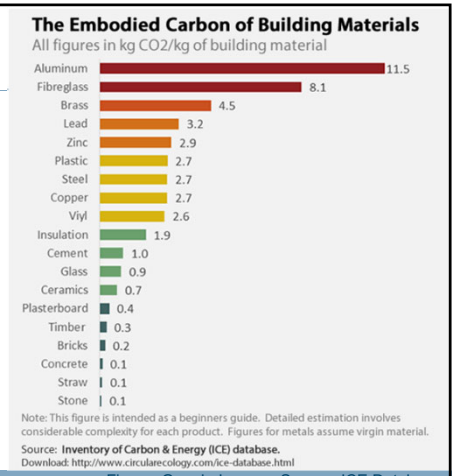


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Figure: Google Images Source: ICE Database

CONCRETE SUSTAINABILTITY…?

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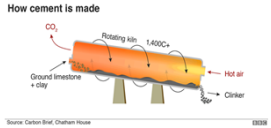
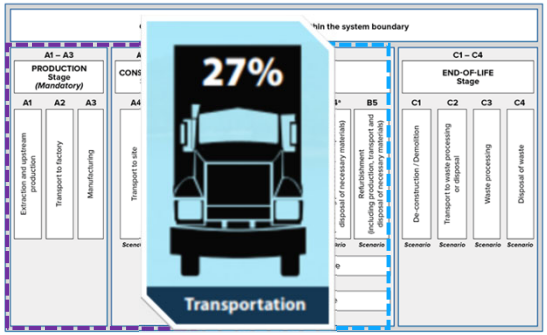
Images: GoogleImages

What are the levers?

- There's **embodied**…. and then there's **use phase** emissions.
  - ~90% of embodied CO2 is from cement production.



  - Use phase emissions…



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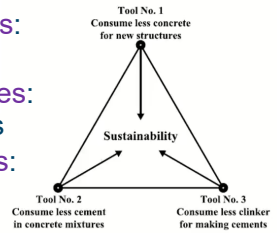
Figures: Chatham House/BBC; ISO 21930

Specific levers to reduce **embodied** CO2…

1) Consume less concrete for new structures:
   - Be efficient with our pavement designs
2) Consume less cement in concrete mixtures:
   - Optimizing our concrete paving mixtures
3) Consume less clinker for making cements:
   - Embrace lower carbon cements



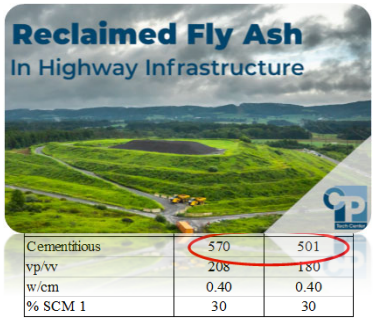
Come a long way already…. will continue to improve!

[Source: Mehta, CI February 2009]

1) Consuming Less Concrete: Being efficient with our pavement designs!

- Use the best available design tools
  - Pavement ME Design
- Specify **Long-life**
  - Low hanging fruit (double life → almost halve CO_2)
  - Quality construction!
- Concrete Overlays
  - Capitalize on equity already in pavement
  - Long-life and low-carbon design solution
  - EDC6 TOPS recognizes this opportunity

2) Consuming Less Cement in Concrete Mixtures: Optimizing our Concrete Pavement Mixtures



Cementitious	570	501
vp/vv	208	180
w/cm	0.40	0.40
% SCM 1	30	30

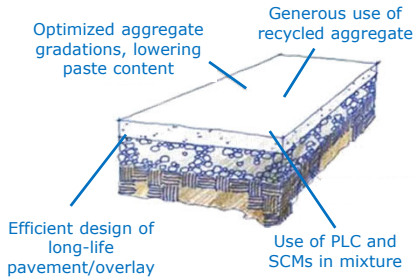
3) Consume less clinker for making cement: Embrace Lower Carbon Cements

- Specify and adopt Portland Limestone Cements (PLC)
  - Reduce CO_2 footprint by ~10%
  - Same concrete performance characteristics
  - Better particle packing & nucleation sites
- Consider alternative low carbon cements
  - Geopolymer Concrete
  - Alternative Pozzolanic Materials (ground glass, rice husks, etc) MnROAD test cells.

[Image: GreenerCement.org]

Strategies to lower the embodied footprint

- These strategies can be combined
  - Efficient **long-life** designs, with **optimized** concrete mixtures, using **lower carbon** cements.
  - This is about **ENGINEERING** our designs, constituents and mixtures
  - We can reduce the CO_2 footprint of our paving mixtures drastically…!



Strategies BEYOND the embodied footprint

How do we reduce **use phase impacts**?

- Can we address the **big kahuna** (84%)?
  - Reduced fuel consumption via "Pavement Vehicle Interaction"
    - Smoother = lower fuel consumption
    - Stiffer = lower fuel consumption
  - Fewer closures (longer life)
  - Resilience
- Albedo impacts
- Carbonation

Figure: MIT CSHub

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

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What is Good concrete?

- Sustainable
- Easily constructible
- Long lasting
- Low maintenance
- Cost effective
- Serves its purpose

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How do we know it is good?

- Set the recipe
- Watch the process
- Poke it occasionally
- Wait and see when it dies
- Trust me…
- Or measure things
  - But what things?

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Require the things that matter

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

- Workability (everywhere)

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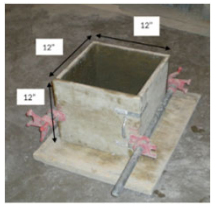
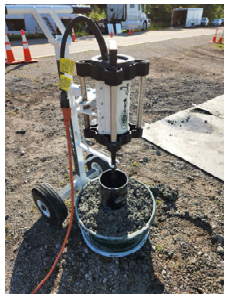
Workability

- Not too wet
- Not too dry

- Prequalification





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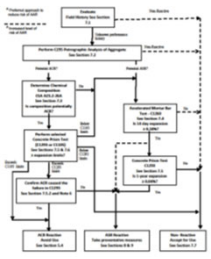
Aggregate Stability

- If aggregates expand = damage
  - Alkali silica reaction
  - D-Cracking

- Follow published guidance

- Prequalification



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AASHTO R80

Transport properties (permeability)

- Keep water out = longer life

- Resistivity

- Control with paste quality

- Prequalification
- QC
- Acceptance

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Cold Weather

- Freeze-thaw
  - Saturation
  - Entrained air
- De-icing salts
  - Sufficient SCM
- Prequalification
- QC
- Acceptance

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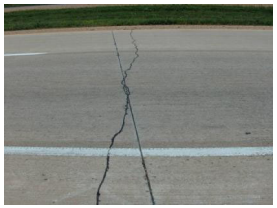
Shrinkage

- Influences cracking risk
- Controls warping
- Takes time
- Paste content (read the batch sheet)



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Strength

- Strong enough to carry loads
  - Cylinders
  - Beams
  - Maturity
- Prequalification
- QC
- Acceptance

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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	✓	-	-	-	✓✓	-

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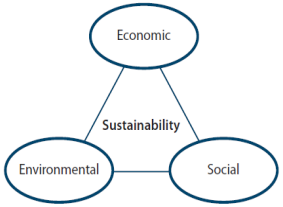
Tying it all together

- 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



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What has changed?

- Agencies are:
  - Dropping minimum cement contents
  - Using tests that better measure potential performance
  - Able to adopt sustainable practices with confidence
- Contractors are:
  - Reducing construction impacts
  - Reducing embodied carbon

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ACPA

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

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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

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Charles Alexandre de Calonne, 1794

Where next?

- Keep encouraging the community to adopt change
- Keep working on:
  - Alternative materials
  - Developing the tools to quantify concrete in the field
    - Improve uniformity
    - Understand vibration
    - Measure bleeding in the field

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