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Carbonate Cement Concrete – A Driver for a Sustainable CO_2 Distribution Network

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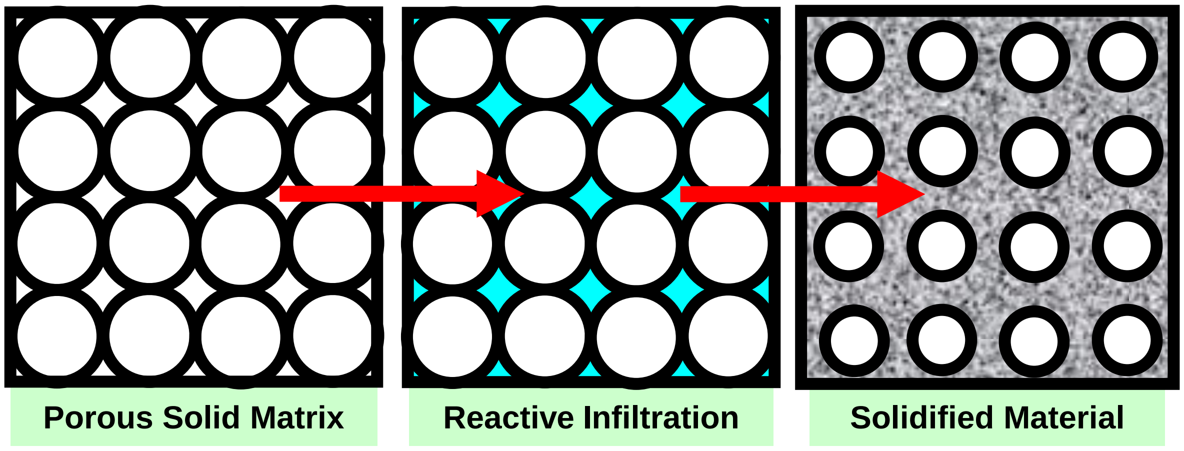
CO_2 and Climate Change

- Power plants and vehicles are mostly responsible
- Portland Cement (PC) is next on the list the world’s largest single industrial emitter of CO_2 – 4 Bt/y
- Cement consumes 3 B gal/y of H_2O and cannot be easily deployed in arid environments
- PC concrete (PCC) is the second most widely consumed material in the world

Rutgers has solved the cement problem

Utilization of CO_2



$$CaSiO_3 + \mathbf{CO_2} = CaCO_3 + SiO_2$$

1st commercially manufactured carbonate-bonded material

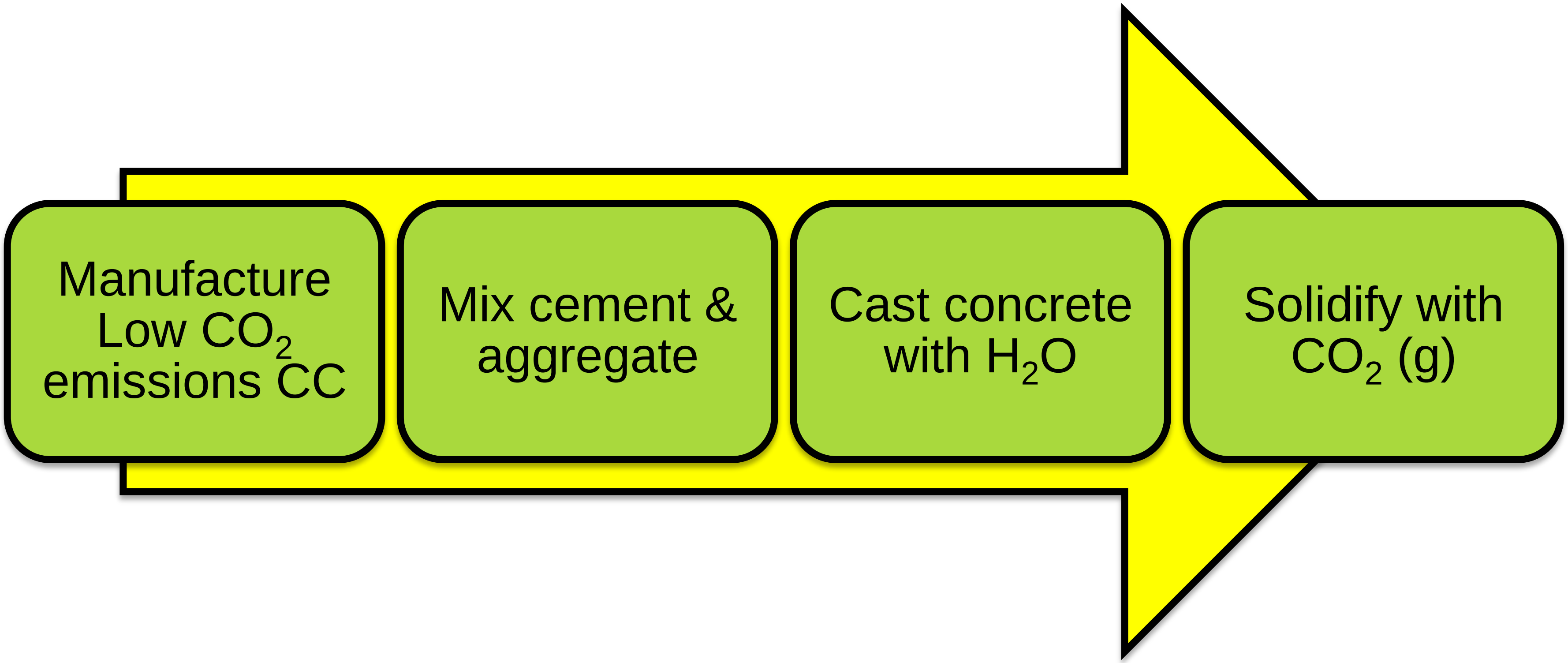
Why is this different from PCC?

- Carbonate cement (CC) and aggregate is packed and then solidified with CO_2
- $CaSiO_3$ is used instead of Ca_2SiO_4 and Ca_3SiO_5 for hardening
- Water is not consumed – no hydration
- Carbonation reaction is easier to control and faster
- No shrinkage
- Stronger and more abrasion resistant
- More chemically durable

Similar to PC with more good differences

- CC can be made with same raw materials as PC
- Conventional cement mill can be used to produce CC
- Limestone content is ~30 % less than PC
- Lower purity grade limestone can be used
- Reaction temperature is 250˚C lower
- More sustainable
  - 30 % less energy
  - 30 % less CO_2 emissions (before CO_2 curing)

How everything works together



Carbonate cement concrete

Solidia Technologies

Paver Samples

Solidia Technologies

Carbonate Concrete w/with PC Concrete

Performance Characteristic[1]	HFC Concrete	FHWA HPC Performance Grade[1]			
		1	2	3	4
Freeze/Thaw Durability (x = relative dynamic modulus of elasticity after 300 cycles)	≈87%	60% ≤ x ≤ 80%	80% ≤ x	NA	NA
Scaling Resistance (x = visual rating of the surface after 50 cycles)	0	x = 4,5	x = 2,3	x = 0,1	NA
Abrasion Resistance (x = avg. depth of wear in mm)	0.22±0.07	2.0 > x ≥ 1.0	1.0 > x ≥ 0.5	0.5 > x	NA
Chloride Permeability (x = coulombs)	776±50	3000 ≥ x > 2000	2000 ≥ x > 800	800 ≥ x	NA
Strength (x = compressive strength)	9482±920	6,000 ≤ x < 8,000	8,000 ≤ x < 10,000	10,000 ≤ x < 14,000	x ≥ 14,000
Elasticity (psi) (x = modulus of elasticity)	5.22×10^6	$4\times10^6 \leq x < 6\times10^6$	$6\times10^6 \leq x < 7.5\times10^6$	$x \geq 7.5 \times 10^6$ psi	NA
Shrinkage (x = microstrain)	90	800 > x ≥ 600	600 > x ≥ 400	400 > x	NA
Creep (x = microstrain/pressure unit)	0.06 (@12 mon @3000 psi)	0.52>x>0.38	0.38>C>0.21	0.21	NA

[1] HIGH PERFORMANCE CONCRETE **STRUCTURAL DESIGNERS' GUIDE, Federal Highway, 1st Editiion (2005).**

Sustainability of commercial process

- CO_2 Savings
  - 4 billion tonnes of cement produced in 2015
  - Emits ~4 billion tonnes of CO_2
  - 70% CO_2 emission reduction = 2.8 billion tonnes/y
- Energy Savings
  - 4 Billion tonnes Cement at 4 GJ/tonne
  - 30% energy savings = 4.8 EJ/y
  - 2 20 gal fill ups for every car in the world
- Water Savings
  - 80% water savings of 3 trillion liters =2.4 trillion liters
  - Roughly a glass of water/day for everyone in the world

So…where do we get the CO_2?

- CO_2 suppliers – not enough!
  - 1 tonne of CC requires 200 kg CO_2
  - 4 Bt/y requires 800 Mt/y CO_2
- Storing CO_2 occupies large volume
- If CO_2 becomes a critical material, price will go up
- What are the options?
  - Power plants
  - Industrial waste
  - MSW & biomass

How do we store and handle the CO_2?

- Traditional gas and liquid handling methods
  - Use high CO2 concentration streams
  - Large scale compression capabilities
  - Additional purification needed
  - Limiting factor is where to store the gas
- Solid-state Storage
  - Adsorption methods have low capacity
  - Lots of room for innovation

Solid-state CO_2 capture, storage and supply (CCSS)

Capture & Storage

$$CaSiO_3\,(s) + CO_2\,(g) \rightleftharpoons CaCO_3\,(s) + SiO_2\,(s)$$

Supply

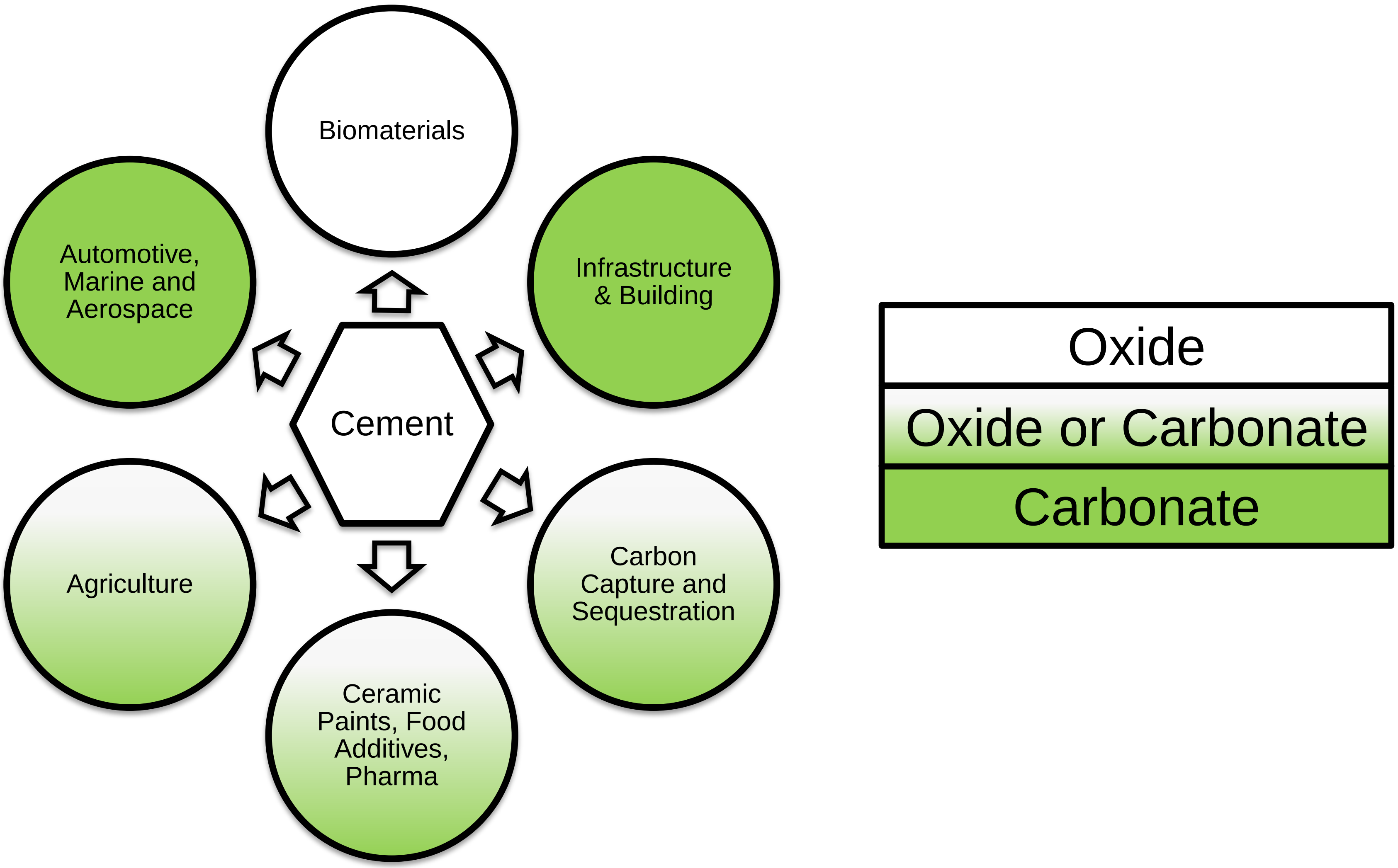
$$CaCO_3\,(s) + SiO_2\,(s) \rightleftharpoons CaSiO_3\,(s) + CO_2\,(g)$$

Reaction can go **forwards and backwards** infinitely

Game-changing green developments

- Make $CaSiO_3$ from $CaCO_3$ + **indigenous materials**
  - Can make anywhere in the world
- First fully recyclable ceramic without melting
  - Rubble from tear downs can be used to build new buildings
- Solid-state methodology for capturing storing and supplying CO_2
- Huge reductions in water, energy, CO_2 and raw materials
- RRTC financed in April to commercialize solid-state CCSS

Driving more CO_2 Utilization



Public-Private Partnerships

RRTC

Solidia Technologies

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