Carbonate Ceramics – A Disruptive Technology for the Brick Industry

Professor Richard Riman:
Rutgers Material Science and Engineering
riman@rci.rutgers.edu
848-445-4946

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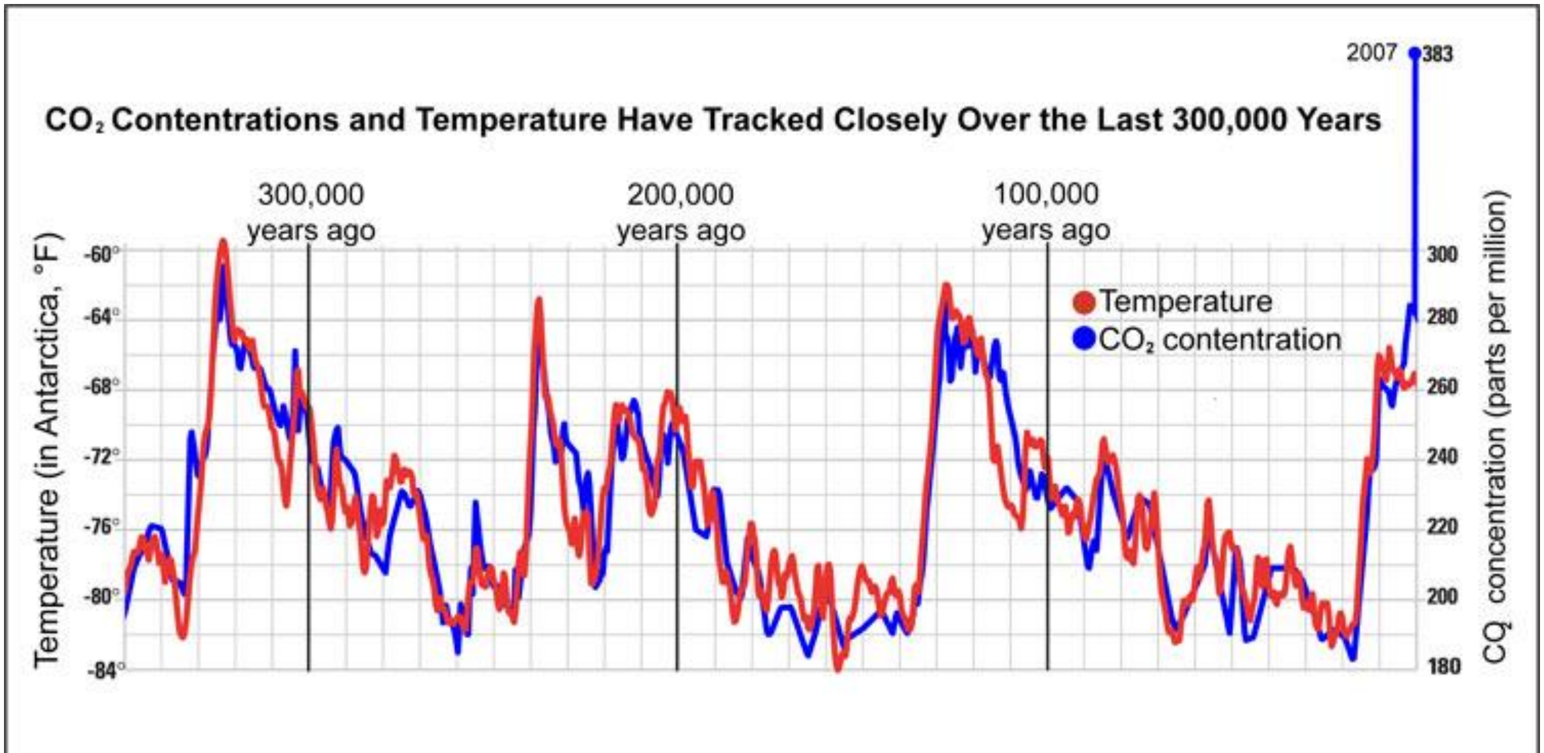
Climate Change…What Me Worry?



http://www.southwestclimatechange.org/climate/global/past-present

Ordinary Portland cement

Concrete

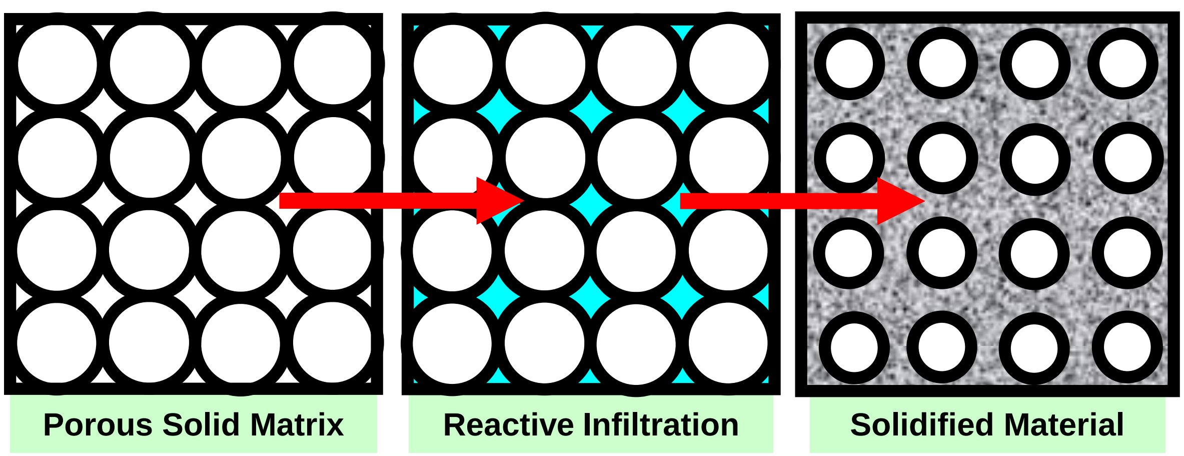
- Composite material made of cement, sand, gravel, and water
- 2nd most consumed resource in world (after water)

Ordinary Portland Cement (PC)

- Ca_2SiO_4 Di-Calcium Silicate
- Ca_3SiO_5 Tri-Calcium Silicate
- Hardens (reacts) with H_2O

Carbonate cement concrete - an RU Innovation

- Patented internationally, licensed globally
- Pack mix to desired shape
  - PC concrete packs & reacts at same time
- React mix with CO_2
  - PC reacts with water



$$CaSiO_3 + CO_2 = CaCO_3 + SiO_2$$

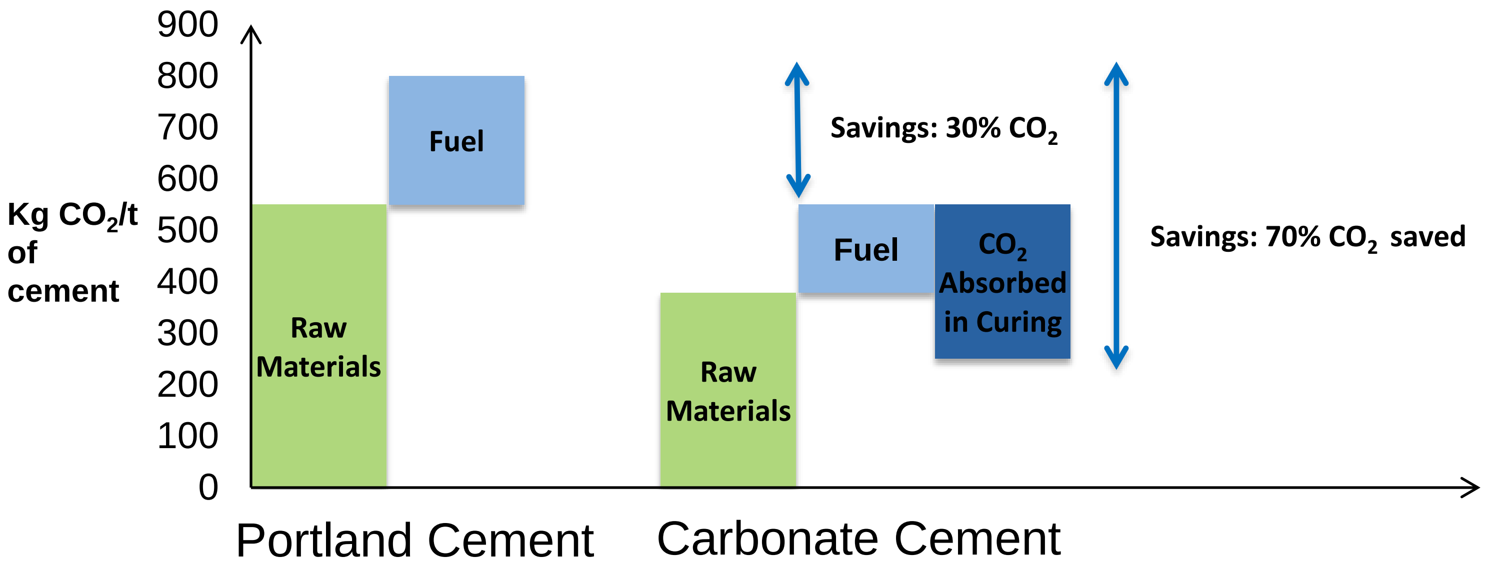
A few facts about calcium silicates

$CaCO_3 + SiO_2 = CaSiO_3$ Does not hydrate, forms @ T>900˚C

$2CaCO_3 + SiO_2 = Ca_2SiO_4$ Hydrates extensively, forms @ T> 1000˚C

$3CaCO_3 + SiO_2 = Ca_3SiO_5$ Hydrates extensively, forms @ T>1250˚C

Carbonate Cement – made at any cement plant



	Portland Cement	Carbonate Cement
Kiln Synthesis Temp	1450°C	1200°C
CO_2 from Fossil Fuels	270 kg/tonne	190 kg/tonne
CO_2 from Calcination	540 kg/tonne	375 kg/tonne
CO_2 for Curing	0 kg/tonne	-300 kg/tonne
Total CO_2 Generated	810 kg/tonne	265 kg/tonne

Carbonate Concrete Advantages

- Cement made at any cement plant for same price or less
  - Less limestone, lower grade acceptable
  - Less fuel b/c less limestone and lower temperature
- Full strength in less than a work shift
- Greater strength than PC concrete at same concentration
- Better chemical durability than PC concrete
- Virtually no shrinkage or creep
- Better temperature stability than PC concrete

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Carbonate cement concrete

Solidia Technologies

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Carbonated C^2 Versus Other Materials

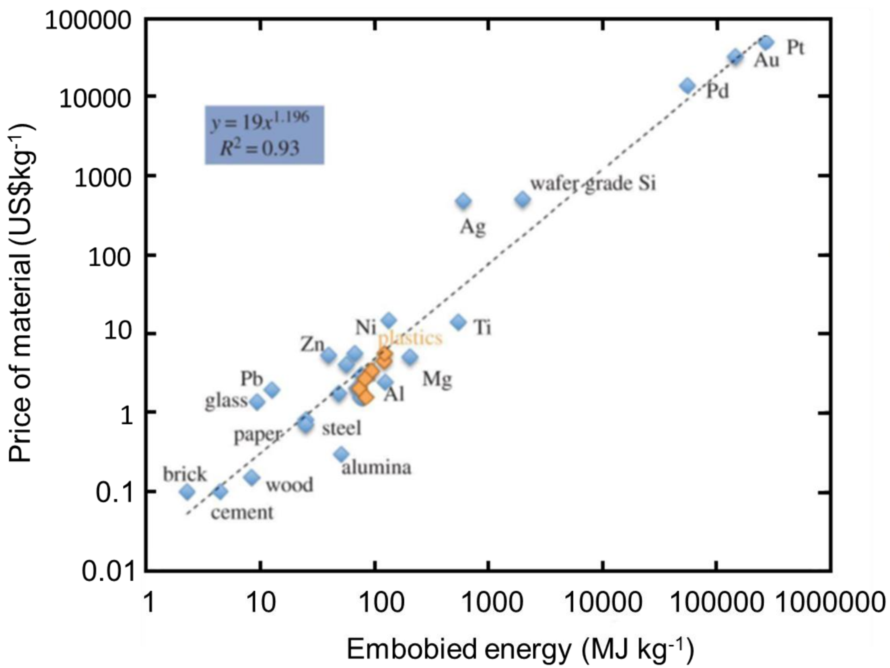
Materials	ρ_{BD} (g/cm^3)	Water Absorption (wt%)	Compressive Strength (MPa)	Flexural Strength (MPa)
Carbonate Cement	2.2	7.37±0.30 (5)	161±16 (5)	18.9±4.6 (15)
Limestone (I)	1.76	<12	>12	>2.9
Limestone (II)	2.16	<7.5	>28	>3.4
Limestone (III)	2.56	<3	>55	>6.9
Travertine	2.30	<2.5	34.5-52	>3.5
Marble	2.59-2.80	0.20	>52	>7
Sandstone	2.00	<8	27.6-68.9	>6.9
Quartzite	2.56	<1	>137.9	>13.9
Granite	2.56	<0.40	>131	>8.27
Structural Concrete	2.3	-	35	6

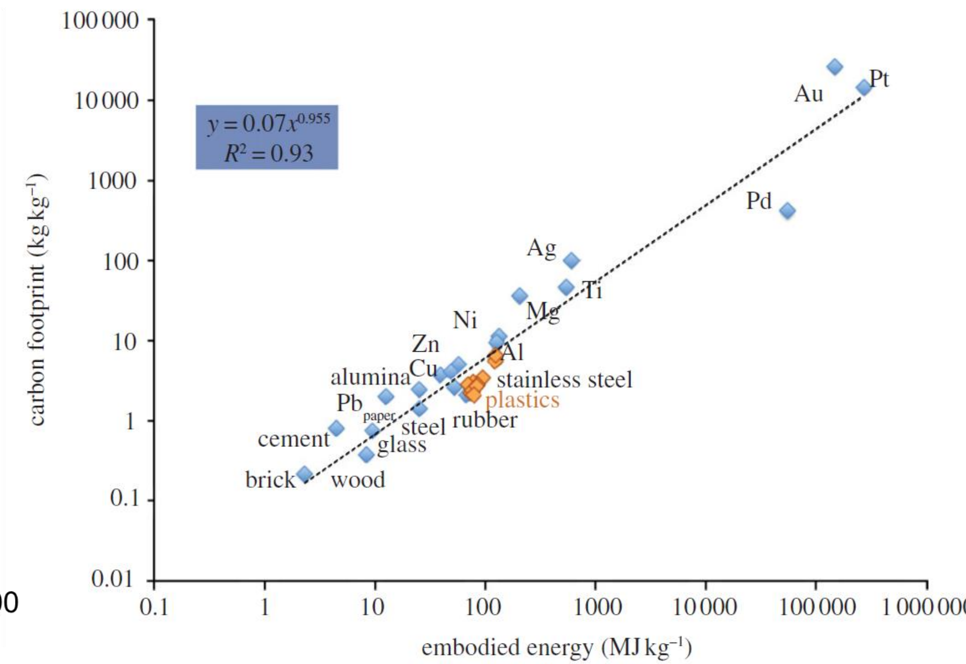
Carbonate Concrete w/with PC Concrete

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	$4\times10^6 \le x < 6\times10^6$	$6\times10^6 \le x < 7.5\times10^6$	$x \ge 7.5 \times 10^6$ 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).**

Brick Energy & CO_2 emissions* - Affordable?





$0.2\ t_{CO_2}/t_{brick}$ @ $25\text{-}45\ \$/t_{CO_2}$

$5\text{-}10\ \$/t_{brick}$

*Timothy G. Gutowskiet al. Phil. Trans. R. Soc. A 2013;371:20120003

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Proposal to structure clay brick manufacturers

- Manufacture structure clay brick product using carbonation instead of firing
- Stronger bricks
- Capability to make a wide range of new products
- Lower fuel costs (~10x, including cement energy)
- Reduce or eliminate, even consume CO_2
- No more shrinkage
- No more warping
- Possible reduction in water usage

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Paver Samples

Solidia Technologies

How difficult is it to switch over?

- Staged transition
  - Install system for capturing and concentrating furnace CO_2 to reduce plant CO_2 emissions
  - RU is in the process of inventing a cheap capture and sequestration system
- Going cold turkey…
  - Continue using your clay but use $CaSiO_3$ as a binder
  - Retrofitting your kiln into a carbonation chamber
  - No pressurization required
  - No heating
  - PTBD system

Summary

- Carbonate ceramics enable structural clay products to transition to green tech with no compromises
- Materials properties comparable to fired brick
- Energy and carbon footprint are substantially smaller
- Technical merit warrants a closer look at the economics

Appendix

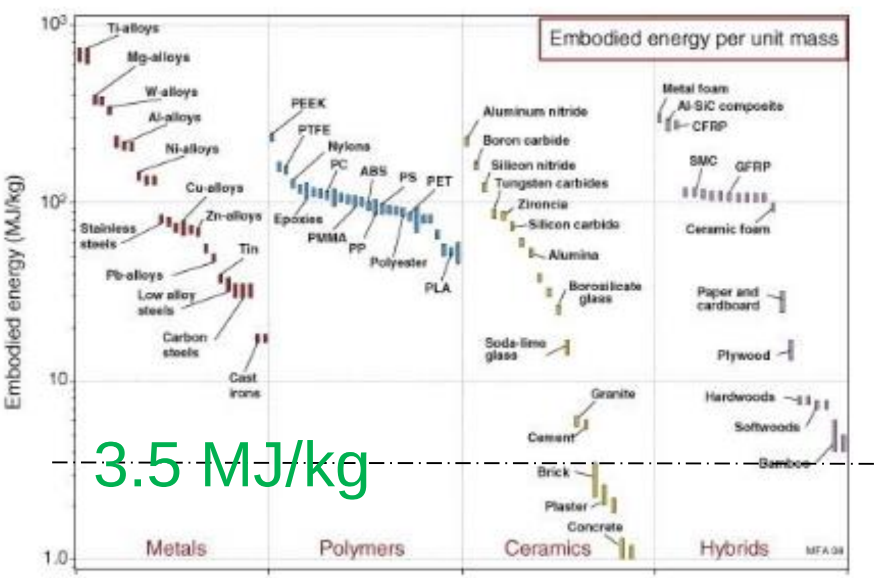
Reasons to not make bricks out of concrete?

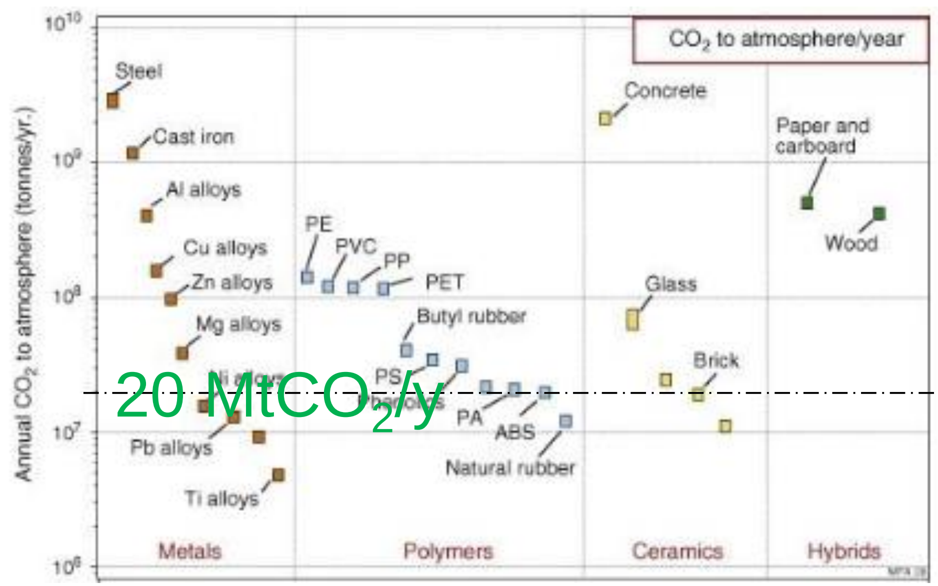
- Durability
  - Alkali-silicate-reaction (ASR)
  - Salt scaling
  - Freeze-thaw durability
- Strength is usually ~3000 psi
- We make our bricks where we mine our clay
  - No way are we going to build a cement plant
- Cost is too high to make fine grain products of controlled color
  - PC is ~70-100 $/tonne
- Any others?

Future challenges for the brick industry

- Widely varying fuel costs for firing
- CO_2 emissions
  - CO_2 tax?
  - Cap & trade
- Products that compete with alternative building materials
  - Thermal properties
  - Strength
  - Cost

Brick Energy consumption and CO_2 emissions*





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$5\text{-}10\ \$/t_{brick}$

Can you afford it?

*Materials and the Environment Eco-Informed Material Choice, Michael F. Ashby