ASCE Florida Chapter East Central Branch
31 March 2022, 12:00 – 1:00 pm

# Concrete Ideas
## for Reducing Carbon Emissions

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1

Whatever their structural system, most buildings and infrastructure projects utilize a significant amount of concrete in their construction. Concrete is a time-tested, reliable material that creates strong, durable, cost-effective structures, however, the manufacture of Portland cement used in concrete creates a large "bloom" of $CO_2$ emissions into the

- Use of Insulated Concrete Forms (ICF) to reduce cement usage in superstructure walls

***How can we reduce our $CO_2$ emissions from concrete and concrete masonry without compromising the performance of our structures?***

*(keeping project costs in mind, of course!)*

2

## Learning Objectives

(i.e. at the end of this session, participants should be able to…)

1. Quantify the approximate $CO_2e$ emissions from concrete, concrete masonry, and grout based on mix design and yardage or volume.
2. Realize the importance of, and potential for, reducing $CO_2e$ emissions from concrete.
3. Learn low- $CO_2e$ alternatives to traditional concrete construction systems that can be implemented with currently available technology and systems.
4. Identify research needs and opportunities that will help to further reduce $CO_2e$ emissions.

3

## Agenda … for the next hour

- The Big Picture
- Concrete and $CO_2e$ Emissions
- Low-Hanging Fruit: Available Strategies
- Strategies Within Reach
- Example Building Comparison
- Some WILD Carbon-Reducing Ideas

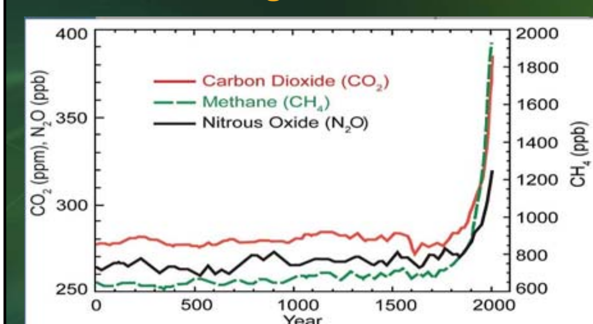
… and spot quizzes throughout!

4

## The Big Picture

5

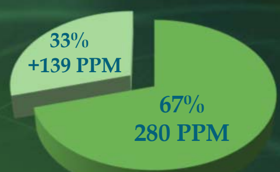
## Global Warming Gases over 2000 years




This graph shows the increase in greenhouse gas (GHG) concentrations in the atmosphere over the last 2,000 years. Increases in concentrations of these gases since 1750 are due to human activities in the industrial era. Concentration units are parts per million (ppm) or parts per billion (ppb), indicating the number of molecules of the greenhouse gas per million or billion molecules of air.

6

## Atmospheric $CO_2$ Increase Since the 1800's

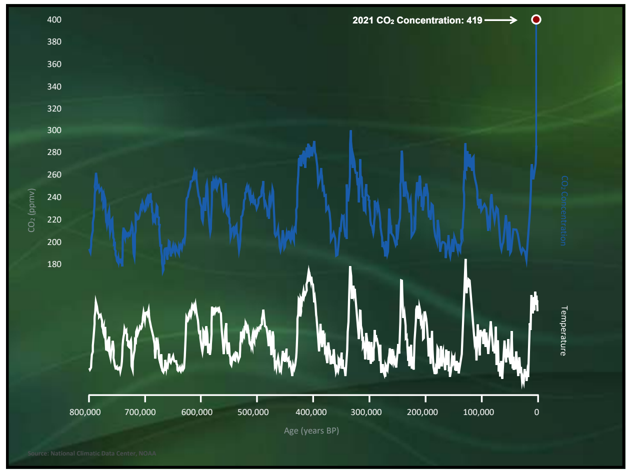



Late 1800's – 280 ppm
January 2021 – 419 ppm

**110 Million Tons** of global warming gases emitted by human activities every day, globally

**280 ppm to 419 ppm = 50% increase in $CO_2$**

7




8

## Spot Quiz Question 1

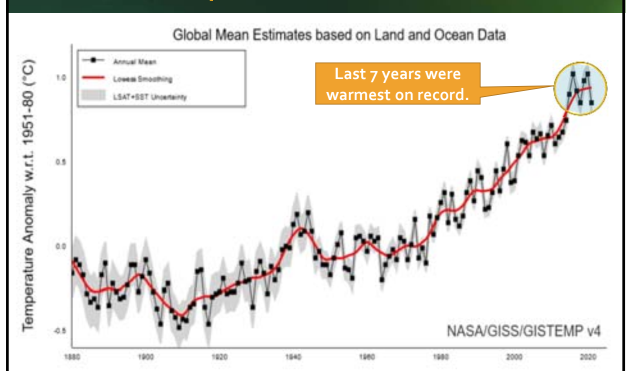
Approximately what percent has the amount of $CO_2$ in the atmosphere increased since the 1800's?

Answer: 280 ppm → 419 ppm =
139 / 280 =

**50%**

9

## Global Temperature Data updated Jan 2022




10

## Global Surface Temperatures

- The Four Major Independent Records


11

## What Has Happened So Far:

- $CO_2$ levels over 419 ppm, compared to historical 270
- 1.8 degree F rise in temperatures since 1880
- 8-inch rise in sea level since 1880s
- Increase in severe drought events + forest fires
- Increase in severe rain events
- Decrease in glacier ice volume

## What Will Happen in the Future:

- Further increase in temperatures, further rise in sea levels, more climate instability
- Further increase in sea levels
- Increase in societal stresses

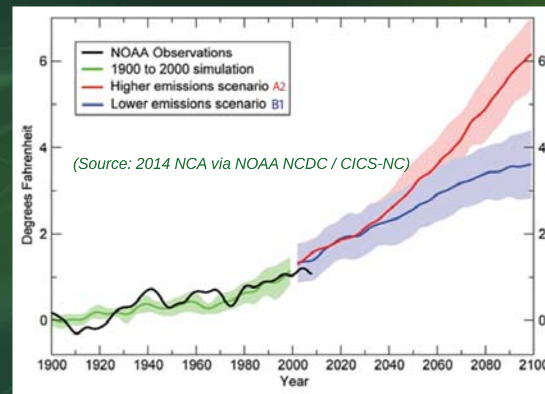
12

## What May – Or May Not - Happen:

- Sea level rise of several feet
- Destabilization of oceanic balances
- Cessation of ocean currents
- Severe climate destabilization, especially northern Europe
- Widespread extinctions
- Severe societal stresses

13

## Our Actions Make a Difference!




14

## ASCE Policy Statement 488 – Greenhouse Gases

July 13, 2019

ASCE supports public and private sector strategies and efforts to achieve significant reductions in greenhouse gas (GHG) emissions through the planning, design, construction, renewal, operation, maintenance and decommissioning of existing and future infrastructure systems. Such strategies can include: (lists ten separate strategies)

https://www.asce.org/issues-and-advocacy/public-policy/policy-statement-488---greenhouse-gases/

15

## American Institute of Architects (AIA) Resolution for Urgent and Sustained Climate Action

- June 2019 - Passed 4860 to 312 (94% of 5172 delegates)
- "Be it resolved that, commencing in 2019 and continuing until zero-net carbon practice is the accepted standard of its members, the AIA prioritize and support urgent climate action as a health, safety, and welfare issue, to exponentially accelerate the 'decarbonization' of buildings, the building sector, and the built environment"
- Resolution calls for AIA to engage members, clients, policymakers, other professional organizations, and the public through "a multi-year strategy for education, practice, advocacy, and outreach."

16

## The SE 2050 Challenge

***All structural engineers shall understand, reduce and ultimately eliminate embodied carbon in their projects by 2050.***

**61 structural engineering firms signed on as of 10 Oct 2021!**

***The Carbon Leadership Forum***

http://www.carbonleadershipforum.org/projects/se2050/

17

## NYS Climate Leadership and Community Protection Act

- Requires NYS to cut **60%** of its statewide carbon emissions (from 1990 levels) by **2030** (or a 40% reduction) and **85%** by **2050** with that remaining 15% from carbon credits.
- NYS is required to produce **70%** of its electricity production from renewable sources by **2030**.
- Carbon emissions in the electricity sector are to be eliminated by **2040**.
- A 22-member climate council made of state agency representatives is charged with ensuring it happens.
- At least **35%** of funds from the state's clean energy program are to go toward disadvantaged communities which will be identified by the Department of Environmental Conservation.
- See www.nyrenews.org/what-we-do/

**"CLCPA" – became law July 2019**

18

## Concrete and Concrete Masonry…

- Are ***ubiquitous*** in building construction
  - Foundations
  - Slabs – framed and on grade
  - Concrete vs. steel superstructure framing
  - CMU vs. cold-formed steel stud walls
- Are strong, durable, well-understood
- Thermal mass reduces building energy demand
- 100-year history of being used for construction
- Cost-effective construction systems
- ACI, PCA PCI, NRMCA, NCMA, …

19

## $CO_2e$ of Portland Cement

Production of Portland cement accounts for 5 to 7% of the worldwide ***anthropogenic*** $CO_2$

- About half is a byproduct of the chemical reaction
- About half is produced by heating - 2,700 $^oF$

About 6 billion cubic yards of concrete is placed every year

Portland cement plant in Alpena, MI

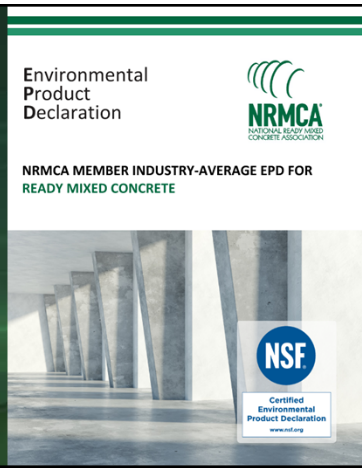
20

## EPD 2020

**Approximations**

- 1.3 lbs. $CO_2$ for every 1 lb. of Portland cement in the mix *
- 0.15 lbs. $CO_2$ for every 1 lb. of concrete placed *
- Varies from about 450 to 850 lbs. per cubic yard *

* - Not including delivery to jobsite, placement, forms, waste, end-of-life impacts.




21

**CARBON PALLET** Pounds of $CO_2e$ emitted per pound of building material

Jim D'Aloisio jim@greenerstructures.com Updated 12-Sep-2021

**CARBON PALLET - STRUCTURAL MATERIALS**

| | | Cradle-to-Gate | | | Cradle-to-Finished-Building | | | |
|---|---|---|---|---|---|---|---|---|
| **MATERIAL** | **lbs./c.f.** | **kg $CO_2e$/CY** | **lbs. $CO_2e$/CY** | **lbs. $CO_2e$/lb.** | **Waste Est.** | **Constr. Est.** | **lbs. $CO_2e$/lb.** | |
| Concrete - 0-2500 psi with 0-19% SCM | 145 | 237 | 521 | 0.13 | 5% | 12% | 0.16 | 6-Jan-2020 |
| Concrete - 0-2500 psi with 20-29% fly ash | 145 | 204 | 449 | 0.11 | 5% | 13% | 0.14 | 6-Jan-2020 |
| Concrete - 0-2500 psi with 30-39% fly ash | 145 | 186 | 410 | 0.10 | 5% | 15% | 0.13 | 6-Jan-2020 |
| Concrete - 0-2500 psi with 40-49% fly ash | 145 | 168 | 369 | 0.09 | 5% | 16% | 0.11 | 6-Jan-2020 |
| Concrete - 0-2500 psi with 30-39% slag | 145 | 184 | 405 | 0.10 | 5% | 15% | 0.12 | 6-Jan-2020 |
| Concrete - 0-2500 psi with 40-49% slag (EPD says 40-39% | 145 | 166 | 366 | 0.09 | 5% | 16% | 0.11 | 6-Jan-2020 |
| Concrete - 0-2500 psi with >50% slag | 145 | 149 | 327 | 0.08 | 5% | 18% | 0.10 | 6-Jan-2020 |
| Concrete - 0-2500 psi with >20% fly ash and >30% slag | 145 | 149 | 327 | 0.08 | 5% | 18% | 0.10 | 6-Jan-2020 |
| | | | | | | | | |
| Concrete - 2501-3000 psi with 0-19% SCM | 145 | 264 | 581 | 0.15 | 5% | 10% | 0.17 | 6-Jan-2020 |
| Concrete - 2501-3000 psi with 20-29% fly ash | 145 | 227 | 500 | 0.13 | 5% | 12% | 0.15 | 6-Jan-2020 |
| Concrete - 2501-3000 psi with 30-39% fly ash | 145 | 207 | 456 | 0.12 | 5% | 13% | 0.14 | 6-Jan-2020 |
| Concrete - 2501-3000 psi with 40-49% fly ash | 145 | 186 | 409 | 0.10 | 5% | 15% | 0.13 | 6-Jan-2020 |
| Concrete - 2501-3000 psi with 30-39% slag | 145 | 204 | 450 | 0.11 | 5% | 13% | 0.14 | 6-Jan-2020 |
| Concrete - 2501-3000 psi with 40-49% slag | 145 | 184 | 406 | 0.10 | 5% | 15% | 0.12 | 6-Jan-2020 |
| Concrete - 2501-3000 psi with >50% slag | 145 | 164 | 362 | 0.09 | 5% | 17% | 0.11 | 6-Jan-2020 |
| Concrete - 2501-3000 psi with >20% fly ash and >30% sla | 145 | 164 | 361 | 0.09 | 5% | 17% | 0.11 | 6-Jan-2020 |
| | | | | | | | | |
| Concrete - 3001-4000 psi with 0-19% SCM | 145 | 326 | 718 | 0.18 | 5% | 8% | 0.21 | 6-Jan-2020 |
| Concrete - 3001-4000 psi with 20-29% fly ash | 145 | 279 | 615 | 0.16 | 5% | 10% | 0.18 | 6-Jan-2020 |
| Concrete - 3001-4000 psi with 30-39% fly ash | 145 | 254 | 559 | 0.14 | 5% | 11% | 0.17 | 6-Jan-2020 |
| Concrete - 3001-4000 psi with 40-49% fly ash | 145 | 227 | 500 | 0.13 | 5% | 12% | 0.15 | 6-Jan-2020 |
| Concrete - 3001-4000 psi with 30-39% slag | 145 | 251 | 551 | 0.14 | 5% | 11% | 0.16 | 6-Jan-2020 |
| Concrete - 3001-4000 psi with 40-49% slag | 145 | 225 | 496 | 0.13 | 5% | 12% | 0.15 | 6-Jan-2020 |
| Concrete - 3001-4000 psi with >50% slag | 145 | 200 | 440 | 0.11 | 5% | 14% | 0.13 | 6-Jan-2020 |
| Concrete - 3001-4000 psi with >20% fly ash and >30% sla | 145 | 200 | 439 | 0.11 | 5% | 14% | 0.13 | 6-Jan-2020 |
| | | | | | | | | |
| Concrete - 4001-5000 psi with 0-19% SCM | 145 | 400 | 879 | 0.22 | 5% | 7% | 0.25 | 6-Jan-2020 |
| Concrete - 4001-5000 psi with 20-29% fly ash | 145 | 341 | 751 | 0.19 | 5% | 8% | 0.22 | 6-Jan-2020 |
| Concrete - 4001-5000 psi with 30-39% fly ash | 145 | 310 | 681 | 0.17 | 5% | 9% | 0.20 | 6-Jan-2020 |
| Concrete - 4001-5000 psi with 40-49% fly ash | 145 | 276 | 608 | 0.16 | 5% | 10% | 0.18 | 6-Jan-2020 |
| Concrete - 4001-5000 psi with 30-39% slag | 145 | 305 | 671 | 0.17 | 5% | 9% | 0.20 | 6-Jan-2020 |
| Concrete - 4001-5000 psi with 40-49% slag | 145 | 274 | 602 | 0.15 | 5% | 10% | 0.18 | 6-Jan-2020 |
| Concrete - 4001-5000 psi with >50% slag | 145 | 242 | 533 | 0.14 | 5% | 11% | 0.16 | 6-Jan-2020 |
| Concrete - 4001-5000 psi with >20% fly ash and >30% sla | 145 | 242 | 532 | 0.14 | 5% | 11% | 0.16 | 6-Jan-2020 |
| | | | | | | | | |
| Grade 60 Reinforcing Bars | 495 | | | 0.85 | 5% | 5% | 0.94 | |

22

## Spot Quiz Question 2

Approximately how much $CO_2e$ is released, on average, from 10 yards of concrete mixed at a batch plant with 500 lbs. of Portland cement per cubic yard?

Answer: 500 lbs./cy x 1.3 lbs. $CO_2e$/cy cement = 650 lbs. $CO_2e$/cy

X 10 cy =

**6500 lbs. of $CO_2$**

plus transportation to jobsite, placement, & waste

23

## Spot Quiz Question 3

About 6 billion cubic yards of concrete was placed worldwide in 2018. Approximately how much $CO_2e$ was emitted into the atmosphere from this?

**Assume 600 lbs. $CO_2e$/cy, on average.**

**= 3.6 trillion lbs. $CO_2e$ per year**

**= 1.8 billion tons $CO_2e$ per year**

**= 4.9 million tons $CO_2e$ per day**

**= about 5% of global emissions**

24

## $CO_2e$ of Masonry

No industry-standard EPD (yet)

- Precast Concrete Masonry Units (CMU)
  - Typical footprint similar to concrete
  - Use of fly ash & slag can have significant $CO_2$ redux
  - Ask your supplier for reduced-cement units. Lightweight?
- Masonry Grout
  - Typical footprint similar to concrete
  - Proportion method results in cement-rich grout
  - Use of fly ash & slag can have significant $CO_2$ redux
- Other Masonry Products
  - Brick – Clay firing, transportation
  - Stone – Harvesting, finishing, transportation
  - Fly Ash Brick – NO cement, NO firing, transportation

25

## Low-Hanging Fruit: Available Strategies

- Use Supplementary Cementitious Materials
- Reduce concrete volume
- Do not over-specify concrete strength
- Consider frost-protected shallow foundations
- Masonry: Ask CM supplier for low-cement units
- For grout, use SCM and strength-based specification (not proportion-based spec)

26

## Use of Supplementary Cementitious Materials (SCMs)

- Fly Ash
  - Byproduct of coal-fired electric and steam generating plants
  - Type C and Type F - both used for concrete
  - 15 - 25% cement replacement, typical
- Ground Granulated Blast-Furnace Slag (GGBFS)
  - Co-generated during the refinement of iron from iron ore
  - Must be ground to cement-grain fineness
  - Effect on concrete is similar to Fly Ash
  - 25 - 50% cement replacement, typical
- Silica Fume (aka Microsilica)
  - Produced in the refining of silicon metal or ferrosilica alloys
  - Very fine particles. Increases water demand. “Sticky” concrete
  - Increases strength, adhesion, decreases permeability
  - 7 - 10% cement replacement, typical

**Others**
- Rice Hull
- Ground Glass
- More

27

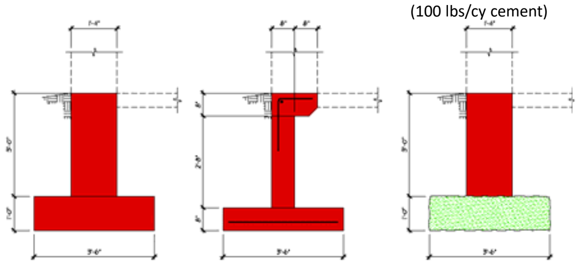
## Fly Ash Types C or F

- The use of fly ash in concrete:
  - Reduces permeability
  - Slightly delays strength gain
  - Slightly reduces shrinkage
  - Reduces heat of hydration
  - Increases workability
  - Increases resistance to ASR
  - Slightly higher ultimate strength
  - Reduces and delays bleeding
- Other Effects
  - Reduces the amount of $CO_2$ generated
  - Reduces the amount of waste disposed in landfills
  - May reduce cost

28

## Conventional Foundations: Alternatives to the Conventional

STANDARD | OPTIMIZED | FLOWABLE FILL (100 lbs/cy cement)

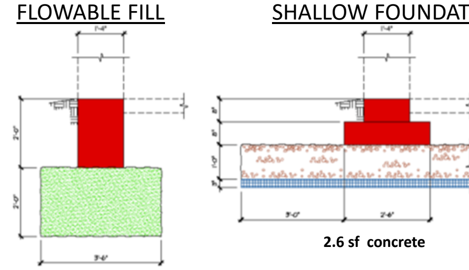


7.7 sf concrete | 5.0 sf concrete | 4.0 sf conc; 3.5 sf flowable fill

29

## Conventional Foundations: Alternatives to the Conventional

DEEP-TRENCH FLOWABLE FILL | FROST-PROTECTED SHALLOW FOUNDATION

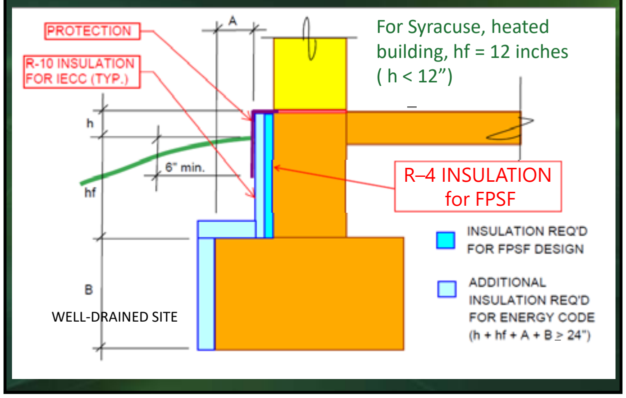


2.7 sf conc; 7.0 sf flowable fill | 2.6 sf concrete

Standard: 7.7 sf concrete

30

## FPSF and Energy Code Foundation Design




31

## Frost-Protected Shallow Foundations

- Industry-standard design guides available
- Required to be used by some large clients
- Can save money, time, and GWP gas emissions (in several ways)
- Watch the type of insulation used!
- Highly detail- and construction-sensitive



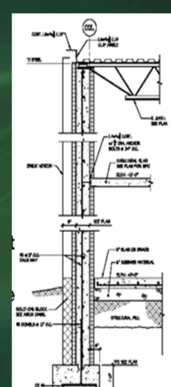
32

## Strategies Within Reach

- Use high-volume SCM
- Use Portland-limestone or blended cement
- Specify maximum amount of Portland cement
- Foundation optimization
- Use crystalline waterproofing admixture to reduce cement requirements
- Use voided slab systems for two-way slabs

33

## Insulated Concrete Forms (ICFs)



- Structurally – reinforced concrete walls and beams
- Connections penetrate inner insulation layer
- Remove inner insulation at slabs at retaining walls
- Inspection during concrete placement is critical
- Can use high volume fly ash concrete

34

## Insulated Concrete Forms (ICFs)

Boys and Girls Club of Binghamton

Completed 2009

35

## Insulated Concrete Forms (ICFs)


Worcester CSD

Completed 2013

36

## Portland-Limestone Cement

United States

LafargeHolcim | About Us | Solutions & Products | Sustainability | Newsroom | Careers

Holcim Worldwide

**LafargeHolcim in the US Names First Plant in the Nation to Fully Convert to Low-Carbon Portland Limestone Cement**

14 September 2021

**Chicago, IL, September 14, 2021 –** As part of a global effort to adopt more sustainable products and lower the industry's carbon footprint, LafargeHolcim in the US has announced that its plant facility in Midlothian, Texas, will be the first cement plant in the country to fully convert to Portland limestone cement (PLC). The decision is a monumental step in the industry's efforts to provide low-carbon materials and solutions.

***Texas-based Midlothian plant offers OneCem® to help customers meet sustainable construction goals and lower carbon emissions.***

**OneCem®**, a product under **Envirocore™ Cements** – the company's portfolio of blended hydraulic cements and supplementary cementitious materials (SCMs) – is a blended cement manufactured with up to fifteen percent per ton of finely ground high quality limestone. OneCem is an engineered product

37

## Marin County, CA – Low Carbon Concrete Spec

**19.07.050 – Compliance**

Compliance with the requirements of this chapter shall be demonstrated through any of the compliance options in Sections 19.07.050.2 through 19.07.050.5.

**Table 19.07.050** Cement and Embodied Carbon Limit Pathways

| | **Cement limits** for use with any compliance method 19.07.050.2 through 19.07.050.5 | **Embodied Carbon limits** for use with any compliance method 19.07.050.2 through 19.07.050.5 |
|---|---|---|
| Minimum specified compressive strength $f'_c$, psi (1) | Maximum ordinary Portland cement content, lbs/yd³ (2) | Maximum embodied carbon kg $CO_2e/m^3$, per EPD |
| up to 2500 | 362 | 260 |
| 3000 | 410 | 289 |
| 4000 | 456 | 313 |
| 5000 | 503 | 338 |
| 6000 | 531 | 356 |
| 7000 | 594 | 394 |
| 7001 and higher | 657 | 433 |
| up to 3000 light weight | 512 | 578 |
| 4000 light weight | 571 | 626 |
| 5000 light weight | 629 | 675 |

**Notes**

(1) For concrete strengths between the stated values, use linear interpolation to determine cement and/or embodied carbon limits.

(2) Portland cement of any type per ASTM C150.

38

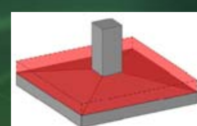
## Marin County, CA – Low Carbon Concrete Spec

**Marin County Low-Carbon Concrete Requirements**

| | | Based on cradle-to-gate EPDs | | | | |
|---|---|---|---|---|---|---|
| Min. specified concrete strength f'c, psi | Max. cement content per cy | Embodied carbon limits, kg CO2e/m3 | Embodied carbon limits, lbs. CO2e/cy | NRMCA EPD 0% SCM, lbs. CO2e/cy | Am't NRMCA w/0% SCM exceeds limits | NRMCA EPD >20% FA and >30% slag, lbs. CO2e/cy |
| Up to 2500 | 362 | 260 | 437 | 521 | 19% | 327 |
| 3000 | 410 | 289 | 485 | 581 | 20% | 361 |
| 4000 | 456 | 313 | 526 | 718 | 37% | 439 |
| 5000 | 503 | 338 | 568 | 879 | 55% | 532 |
| 6000 | 531 | 356 | 598 | | | |
| 7000 | 594 | 394 | 662 | (Add 10 - 20% for waste, transport, placement) | | |
| | 1 - Per Mix | 3 - Per Mix | | | | |
| | 2 - Per Project | 4 - Per Project | | | | |

39

## Concrete Footing Optimization ...a rare story



Conventional spread footings require full depth at face of piers only. Top surfaces can be thinner at edges. 22% concrete redux.

40

## Voided Slab Systems (VSS)

- Voids in concrete at non-structurally critical areas
- Reduces concrete, Portland cement, and weight
- Increases span capacity and/or reduce depth
- Design methodologies based on flat slab design

BubbleDeck

Holedeck

**30–35% typ. reduction in concrete, cement and $CO_2e$**

41

## Example Building Comparison

**BASE CASE**

50,000 sf, two story rectangular building, 25,000 sf footprint, 100 ft X 250 ft., with 12-foot high walls

- 2nd floor – 2-way concrete slab, 25-foot span
- 1st floor – concrete slab on grade
- Perimeter walls 1st-2nd floor – 8" concrete
- Conventional spread footings

Roof framing – steel beams, joist, and roof deck

42

## Example Building Comparison

**MODIFIED CASE**

25% SCM in all concrete, unless otherwise noted

- 2nd floor – 2-way concrete voided slab system
- 1st floor – low strength concrete slab on grade with high-strength flowable fill topping
- Perimeter walls 1st-2nd floor – 8" ICF, 50% SCM
- Frost-protected shallow perimeter foundations

Roof framing – steel beams, joist, and roof deck

43

## Example Building – Base Case

| SYSTEM | $CO_2e$ EMISSONS |
|---|---|
| 50,000 sf, 2-story bldg, 25,000 sf footprint – no SCM in concrete | Assume 3000 psi conc → 350 lbs., 4000 psi conc. → 450 lbs. |
| • 2nd floor – 2-way concrete slab, 25 foot span – 8" thick, 4000 psi | • (25,000 X 8/12) X 450 = 278,000 lbs. |
| • 1st floor – 5" concrete slab on grade, 3500 psi | • (25,000 X 5/12)/27) X 350 = 135,000 lbs. |
| • Perimeter walls 1st-2nd floor – 8" concrete, 4000 psi | • [(2 X 100 + 250) X 12 X 8/12]/27 X 450 = 93,000 lbs. |
| • Conventional spread footings – say 3' deep X 16" wide fd'n walls, avg. 3' wide, 1' deep footings, 4000 psi. | • 700 X [(3 X 16/12) + 3]/27 X 450 = 82,000 lbs. <br> TOTAL $CO_2e$ = 588,000 lbs. (12 psf) |

* - old data

44

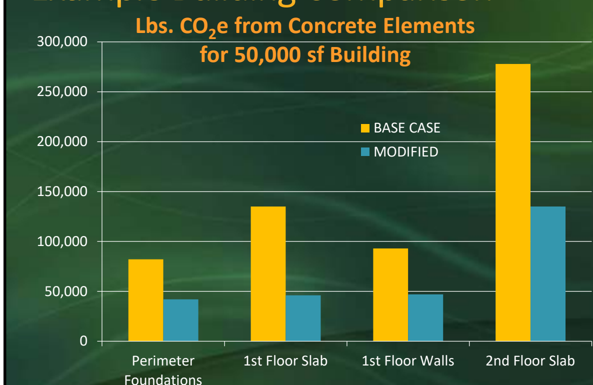
## Example Building – Modified Case

| SYSTEM | $CO_2e$ EMISSONS |
|---|---|
| 50,000 sf, 2-story bldg, 25,000 sf footprint – 25% SCM u.n.o. | Assume 3000 psi → 350 lbs., 4000 psi. → 450 lbs., 500 psi → 75 lbs. |
| • 2nd floor – 2-way voided slab, 25 foot span – 8" thick, 4000 psi | • (25,000 X 8/12) X .65 /27 X (.75 X 450 = 135,000 lbs. |
| • 1st floor – 4" 500 psi conc. with 3/8", 750 lbs./cy topping | • [25,000 X (4/12 X 75) + (.4/12 X 500)] / 27 = 46,000 lbs. |
| • Perimeter walls 1st-2nd floor – 8" ICF conc., 3000 psi, 50% SCM | • [(2 X 100 + 250) X 12 X 8/12]/27 X 450 X .5 = 47,000 lbs. |
| • Frost-protected shallow foundations – say 1' deep X 16" wide fd'n walls, avg. 3' wide, 1' deep footings, 3000 psi. | • 700 X [(1 X 16/12) + 3]/27 X 350 X .75 = 42,000 lbs. <br> TOTAL $CO_2e$ = 270,000 lbs. (5.4 psf) |

* - old data

45

## Example Building Comparison




* - old data

46

## Spot Quiz Question 4

What are some low-cost or no-cost strategies to reduce embodied carbon emissions on your next project?

**Strategies Within Reach**

- Use high-volume SCM
- Use Portland-limestone or blended cement
- Specify maximum amount of Portland cement
- Foundation optimization
- Use crystalline waterproofing admixture to reduce cement requirements
- Use voided slab systems for two-way slabs

**Low-Hanging Fruit: Available Strategies**

- Use Supplementary Cementitious Materials
- Reduce concrete volume
- Do not over-specify concrete strength
- Consider frost-protected shallow foundations
- Masonry: Ask CM supplier for low-cement units
- For grout, use SCM and strength specification (not proportion )

47

## Some WILD Carbon-Reducing Ideas

- Use alternative cements to Portland cement
- Carbon Capture & Storage (CCS)
- Adding C-reducing chemicals to concrete
- Use alternative slab on grade systems
- Use earthen floors
- Allow carbonation to occur over time

~2% benefit

~2% benefit

**"What's the carbon budget for this project?"**

48

## Alternatives to Portland Cement

- Portland-limestone cement / blended cements
- Alkali cements
  - Alkali-Activated Cements (AAC)
  - Aluminosilicate-based alkaline cements
- Geopolymer cements
- Sulfur cement
- Fly ash cement
- Calcium sulfoaluminate-based cements
- Gypsum cements

* More research is needed *

49

## Carbon Capture and Storage (CCS)

https://www.heidelbergcement.com/en/carbon-capture-and-storage-ccs

50

## Concrete Exposure Classes

ACI 318

- Freeze-Thaw Exposure Class F1 (moderate)
  - Concrete exposed to freezing and thawing cycles and occasional exposure to moisture and no deicing salts are used.
  - Min f´c = 4500 psi
- Corrosion Protection Exposure Class C2 (severe)
  - Concrete exposed to moisture and an external source of chlorides in service – from deicing chemicals, salt, brackish water, seawater or spray from these sources.
  - Min f´c = 5000 psi
- **Crystalline waterproofing admixtures and topical applications – do they change exposure class?**

51

## Concrete Slabs on Grade: How Strong Must the Concrete Be?

Typical Concrete Slab Strength: 3000 psi

3000 lbs./in $^2$ X (12 in./ft.)$^2$ = 432,000 psf

Typical Floor Live Loading: 100 psf

432,000 psf / 100 psf = 4,320 use a 2.0 FoS….

*** Most concrete slabs on grade are at least 2,000 times stronger than their required strength! ***

52

## Concrete Slabs on Grade: Alternatives to the Conventional

<u>STANDARD</u>

5" standard concrete on compacted subbase

| Concrete Type, Cement Amount | $CO_2$-e per SF (cradle-to-gate) |
|---|---|
| 4000 psi, 450 lbs./CY | 6.9 |
| 3000 psi, 350 lbs./CY | 5.4 (22% redux) |
| 3000 psi, 20% SCM, 280 lbs./CY | 4.3 (38% redux) |

<u>ALTERNATIVE</u>

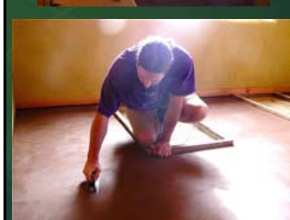
4" low-strength concrete with superplasticizer on compacted subbase w/ 3/8" underlayment topping

| Concrete Type, Cement Amount | $CO_2$-e per SF (cradle-to-gate) |
|---|---|
| 2000 psi, 50% SCM, 150 lbs./CY | 1.8 (70% redux) |
| 500 psi, 50% SCM, 50 lbs./CY | 0.62 (91% redux) |

* - old data

53

## Earthen Floors




54

## Concrete Carbonation


55

## Hopeful Headlines…

News

10 ▪ ENR ▪ September 27/October 4, 2021 enr.com

BUILDING MATERIALS

### Concrete Emissions Could Decrease Even With More Use

An analysis has projected the potential for reduced greenhouse gas emissions from cleaner concrete production, even with increased use of the material. According to a report from researchers at the Massachusetts Institute of Technology, improvements in concrete production and use could reduce GHG emissions 49% in buildings and 14% in paving for new construction between 2016 and 2050. More ambitious efforts could lower emissions by as much as 57% and 65%, respectively, during the same time frame.

One hitch is projections rely on use of available technologies that haven't yet been widely adopted. Jeremy Gregory, the report's lead author and director of MIT's Concrete Sustainability Hub, says risk aversion and cost premiums have slowed the use of new technologies.

The researchers' models predict the use of practices that include 40% clinker replacement and universal use of "average" carbon capture technology by 2050.

More ambitious scenarios have the industry making changes, such as a 19% reduction in concrete consumption per unit of area and reusing 0.1 cu meter of concrete elements per cu meter of concrete produced, plus a greater percentage of clinker replacement and the adoption of "the best performing" carbon capture technology, the report says.

The report found that innovative uses of concrete can play a role in reducing building energy and vehicle fuel consumption over its life cycle. Mike Ireland, president and CEO of the Portland Cement Association, said in a statement the report "encourages life cycle thinking."

Gregory predicts government interest could push the market to make low-carbon options the norm through so-called "buy clean" initiatives. He says he's already seen more transportation departments showing interest in low-carbon concrete for pavement. Ireland agrees that more DOTs are considering it as a factor.

"The industry is also working on new and innovative lower-carbon cement mixes, such as Portland-limestone cement, which has a 10% lower carbon footprint than Portland cement," Ireland said. ▪

*By James Leggate*

56

## Spot Quiz Question 5

Approximately how much $CO_2e$ is emitted per square foot, from a 5-inch thick, 3500 psi slab, with no SCMs?

(Not including delivery to jobsite, placement, waste)

(5" / 12") / 27 cf/cy X <u>**718**</u> lbs/cy

**= 11 lbs/sf**

57

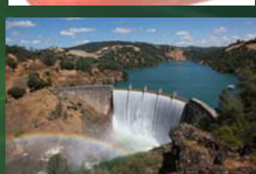
## Recommendations

- Do not over-specify concrete strength.
- Use SCM as much as possible - start at 20%.
- Use flowable fill to reduce footing volume.
- Geometrically minimize foundation concrete.
- Consider use of FPSFs, ICFs, VCSs when appropriate.
- Consider alternative slab on grade systems.
- Encourage use of EPDs, $CO_2e$ tallies of projects.
- Stay tuned for future developments!

58

## The Role of the Engineer




59

## Thank You for Listening!

- Questions?
- What have you learned?
- What will you do?

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60