Cement State of the Union

Paul D. Tennis, PhD, FACI, FASTM
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American Cement Association

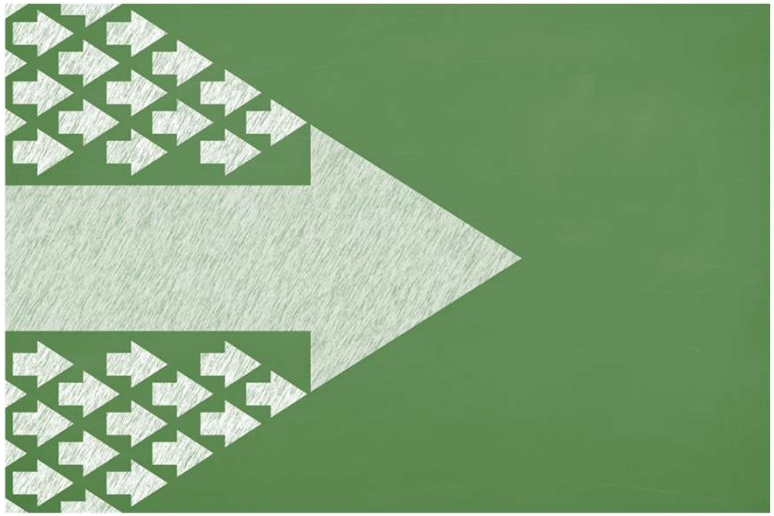
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Outline for Discussion

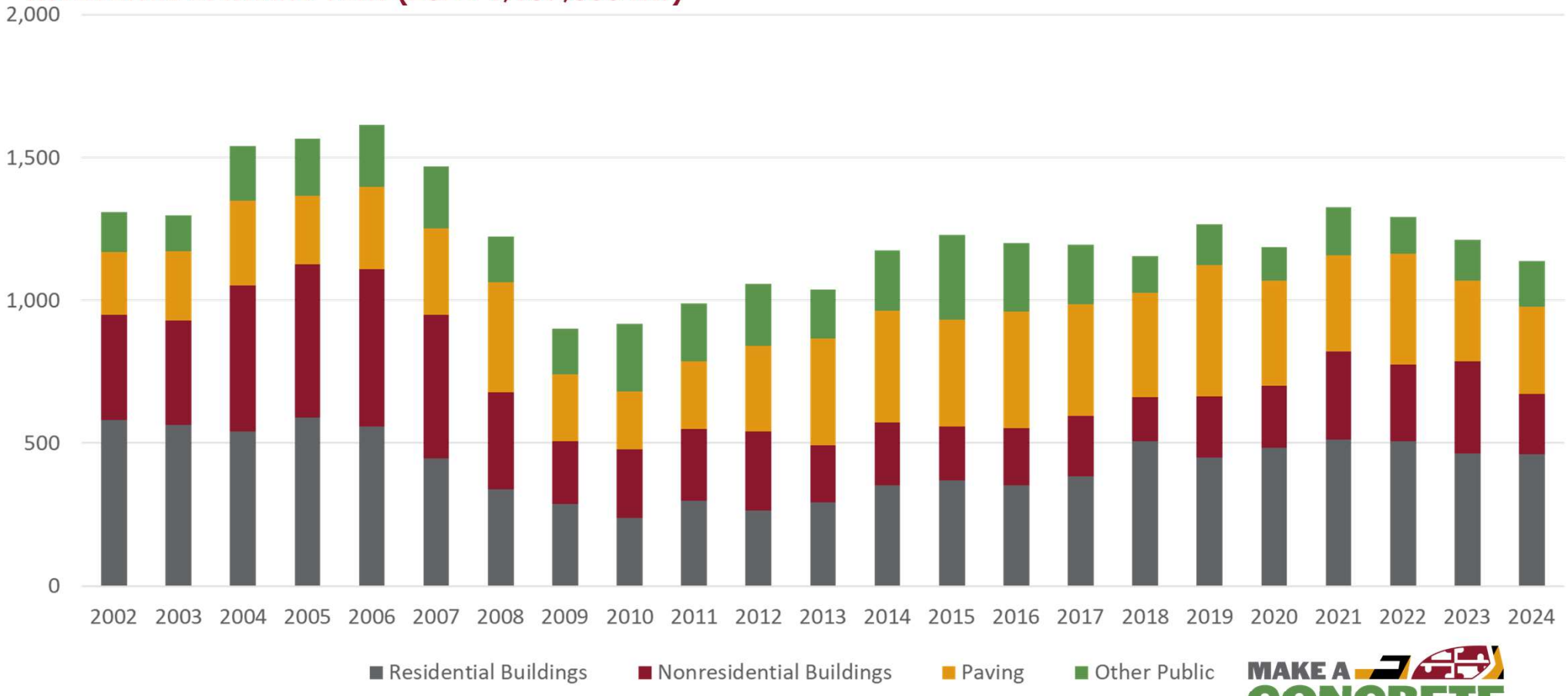
- Cement Consumption and Apparent Use
- Cement Specifications
- Potential Innovations



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Maryland Cement Consumption

Thousands of Metric Tons (2024 1,137,000 MT)

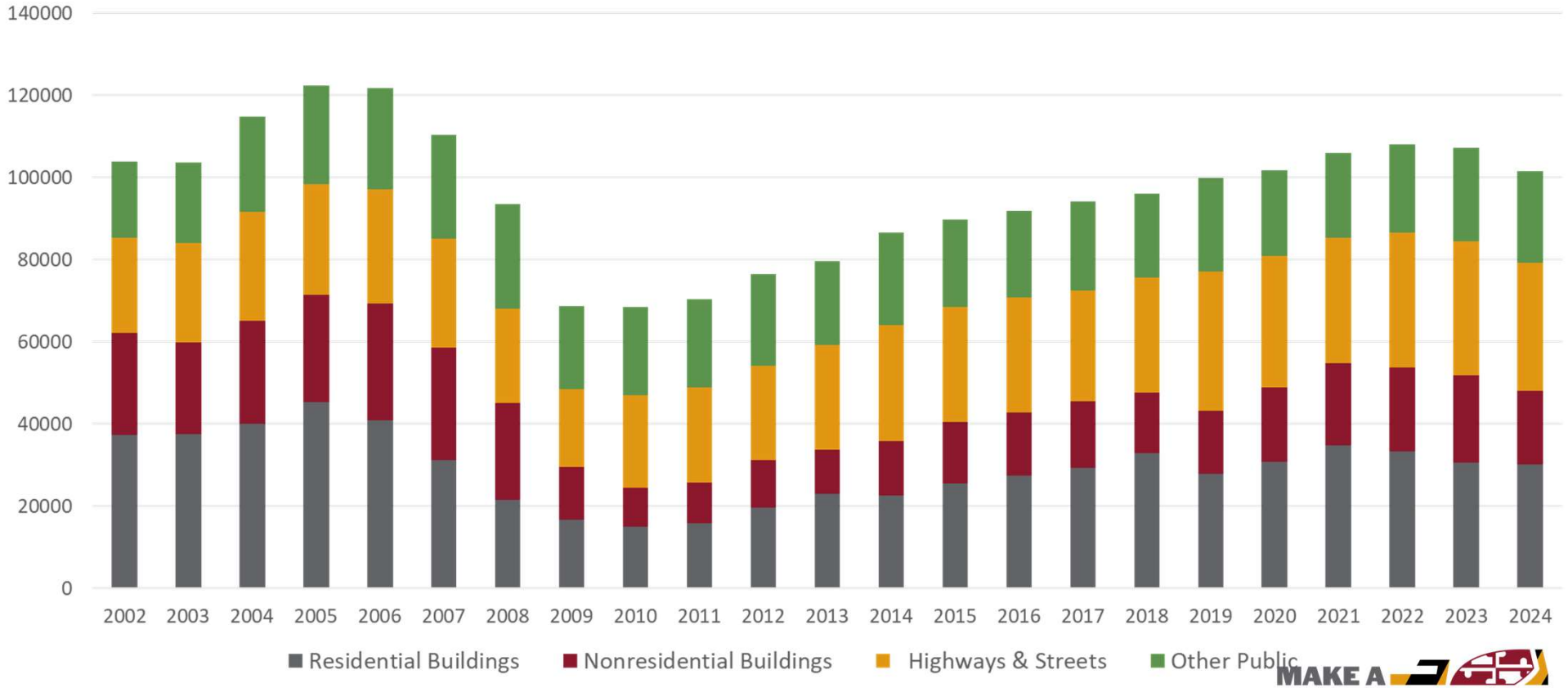


Source: ACA Market Intelligence based on USGS data

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US Cement Consumption

Thousands of Metric Tons (2024 101,570,000 MT)

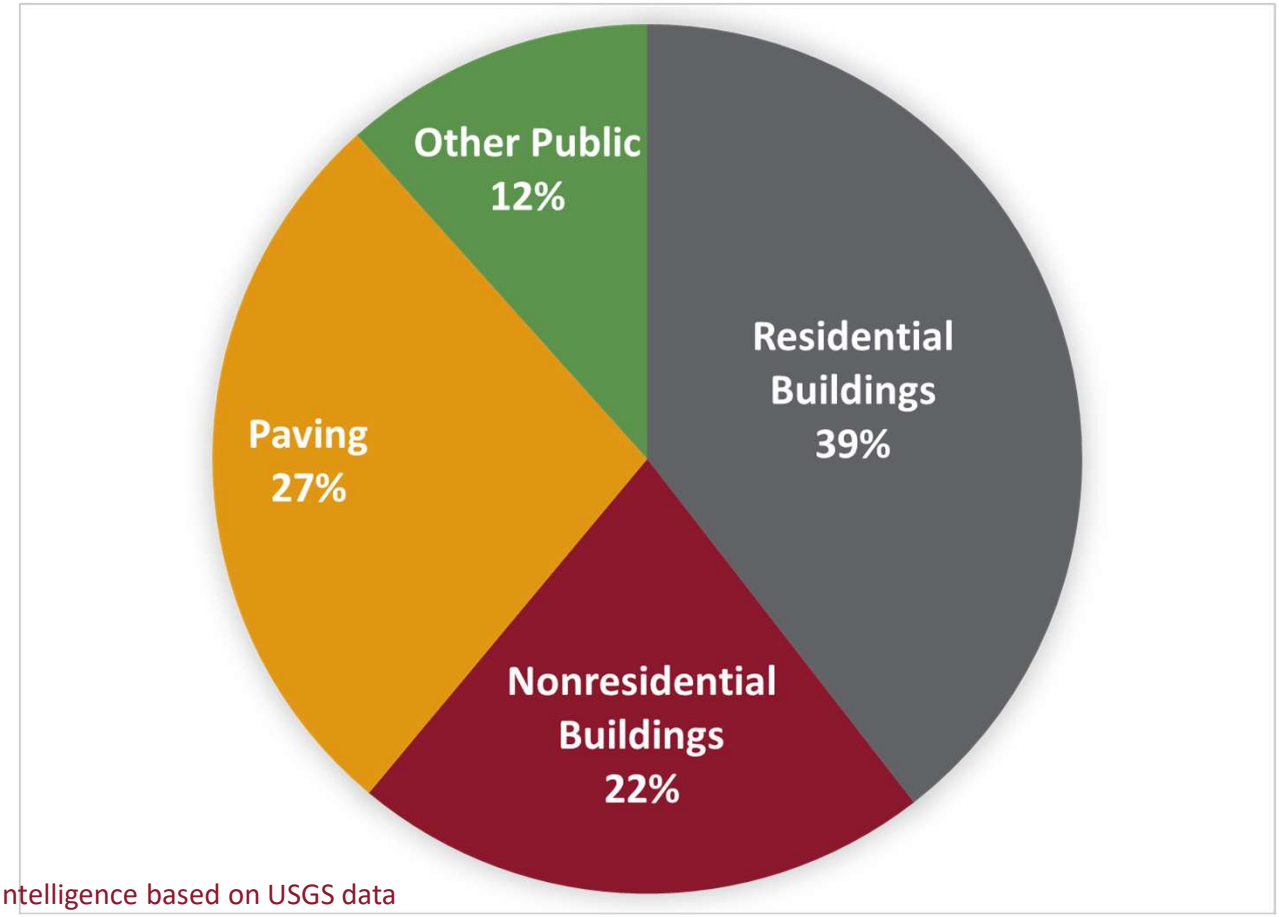


Source: ACA Market Intelligence based on USGS data

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Maryland Distribution of Cement Consumption

5-Year Average Share of Total Cement Consumption (1,230,000 MT)



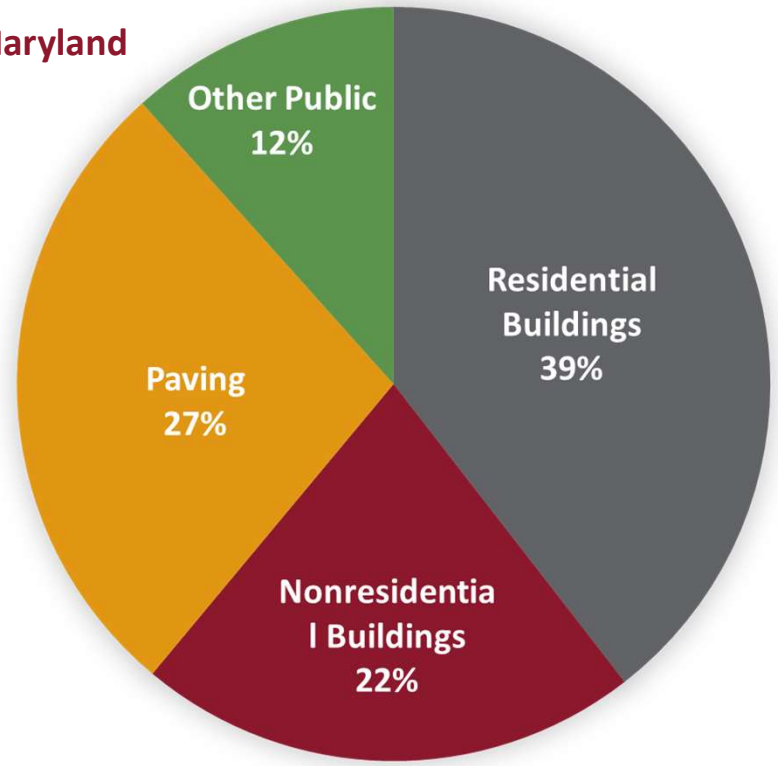
Source: ACA Market Intelligence based on USGS data

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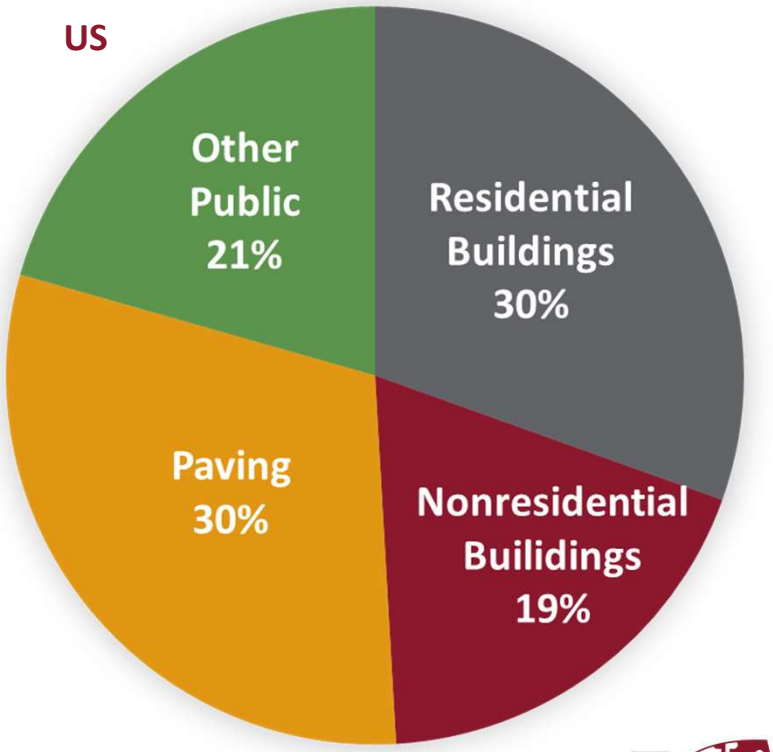
Maryland/US Distribution of Cement Consumption

5-Year Average Share of Total Cement Consumption

Maryland



US

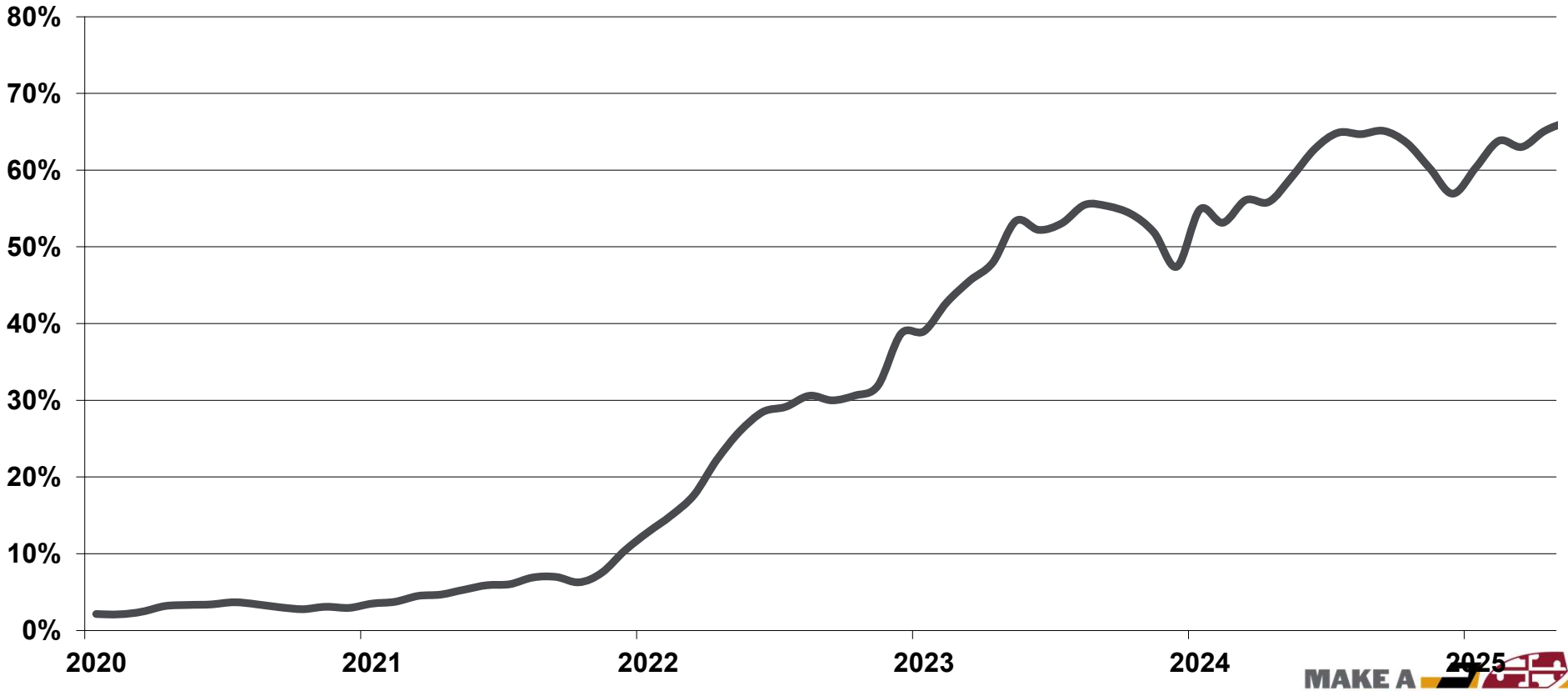


Source: ACA Market Intelligence based on USGS data

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Blended Cement Share in U.S.

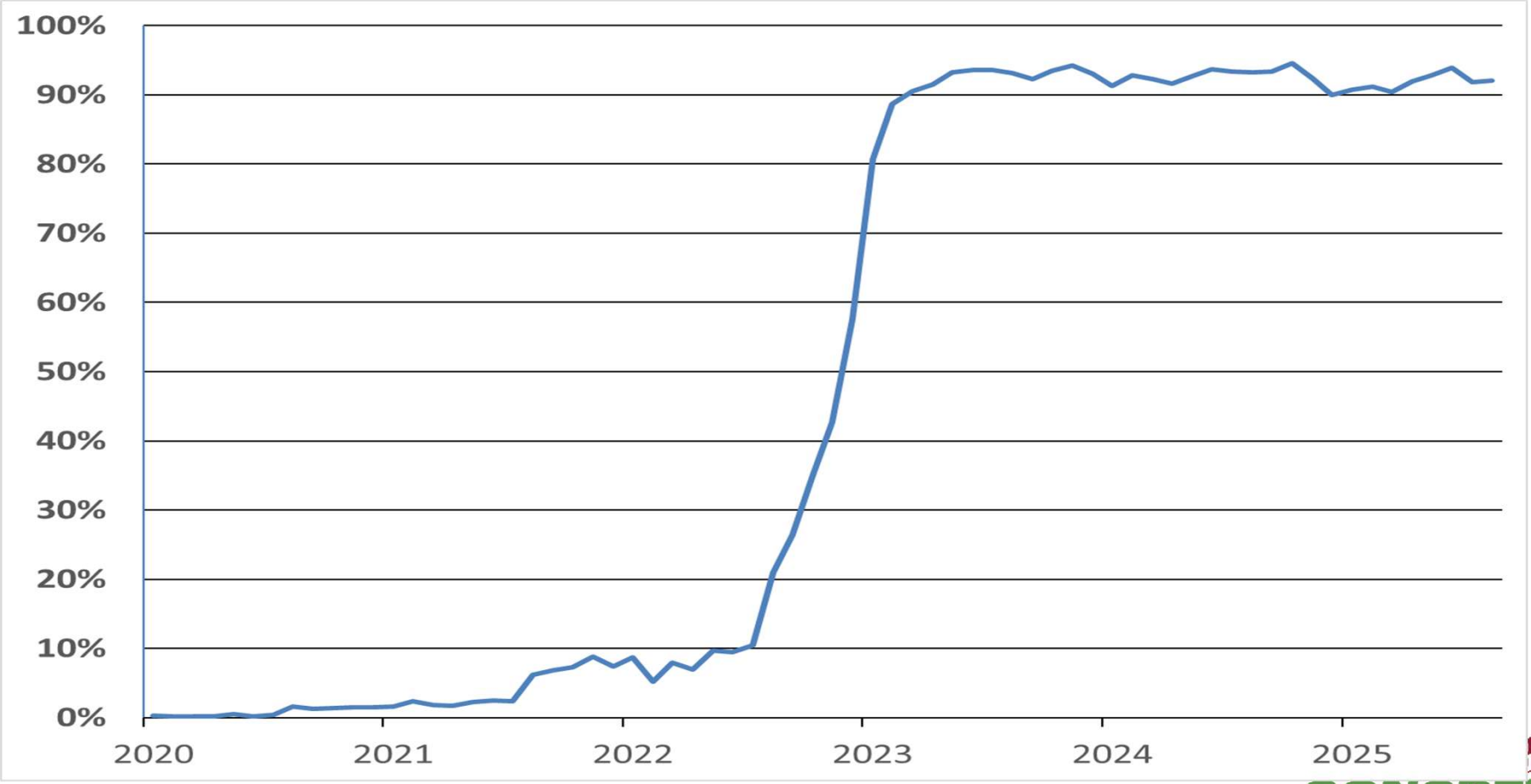
- Aug 2025– U.S. 67.4%,



Source: ACA Market Intelligence based on USGS data

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Blended Cement Share in Maryland



Source: ACA Market Intelligence based on USGS data

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Current State

- Strong use of cement indicating a strong concrete construction market
- Blended cements, particularly Type IL, are the dominant cement used in concrete construction

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Looking Ahead

- Blended cements
- Innovative materials

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ACA Roadmap to Carbon Neutrality



Near-Term

Replace raw materials with **recycled materials**

Produce low-carbon **cement blends**

Optimize designs for the lowest life cycle emissions

2026

YOU ARE HERE

Mid-Term

Increase use of **alternative fuels**

Use **renewable energy**

Long-Term

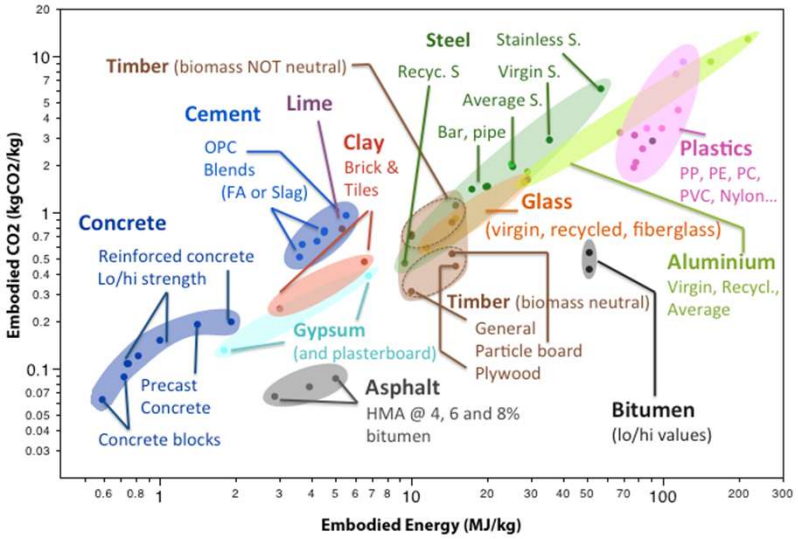
Carbon Capture, Utilization & Storage (**CCUS**)

Introduce new **cement blends**

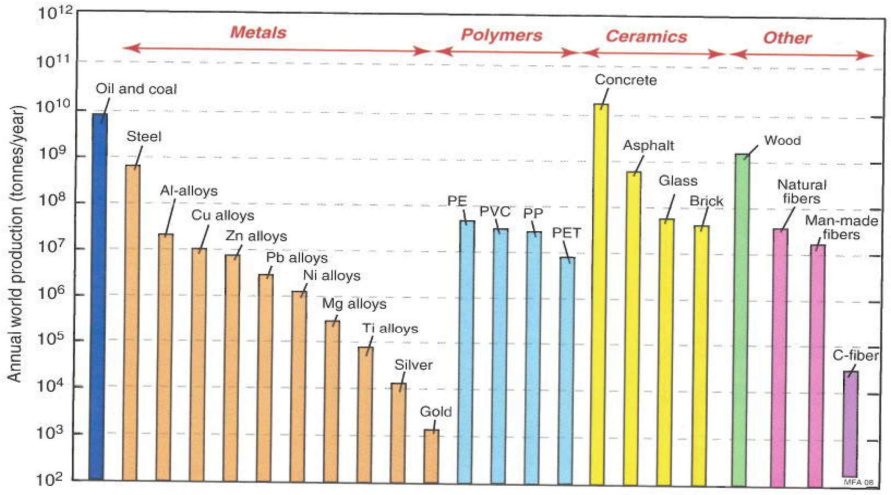
2050

GOAL OF INDUSTRY-WIDE CARBON NEUTRALITY

Why *Large* CO_2 Footprint for Concrete? All Materials Have CO_2 & Energy Impacts



Barcelo, Kline, Walenta (2012)



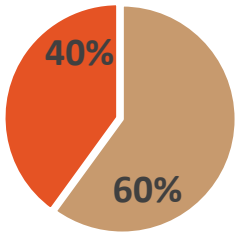
Ashby (2009)

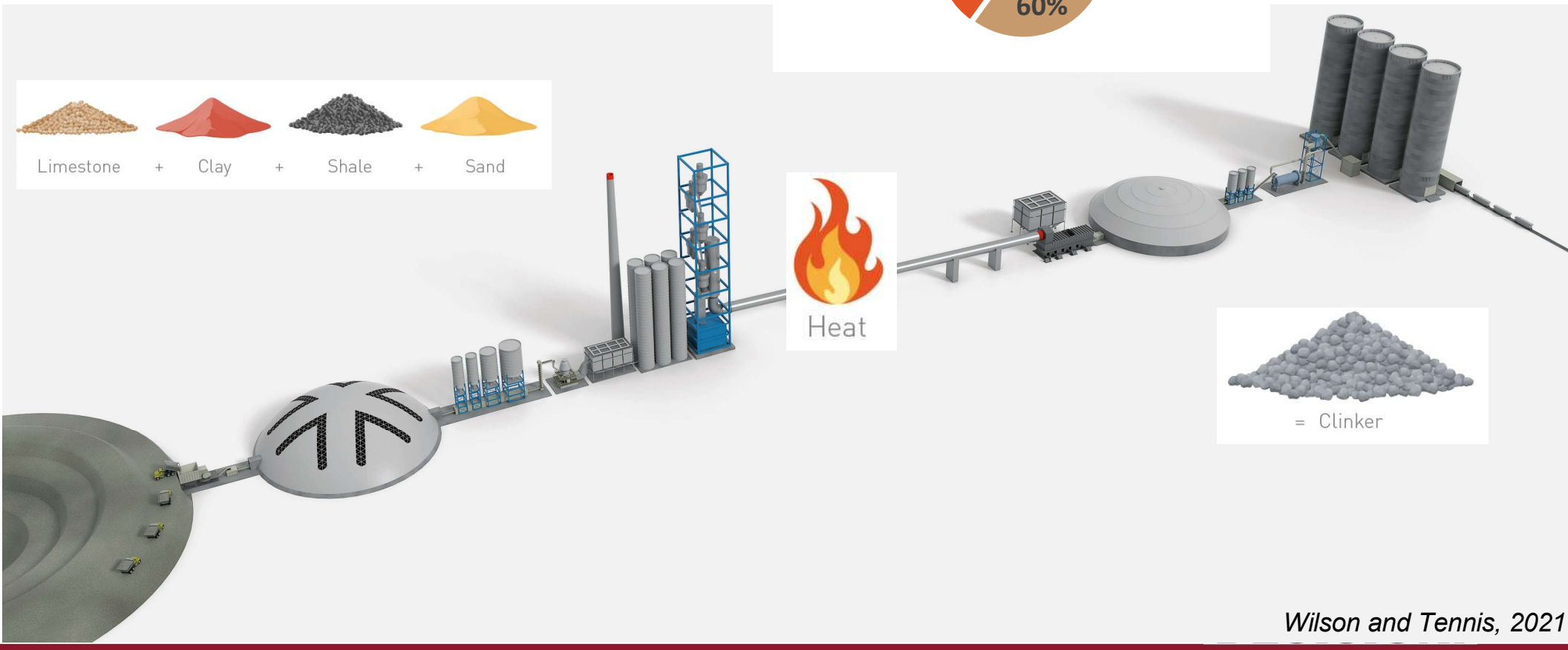
Low CO_2 footprint for concrete (t CO_2/t)

Very large worldwide annual production (t/year)

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Where Does the CO_2 Come From?





Wilson and Tennis, 2021

Near Term Blended Cement Impacts



Actions

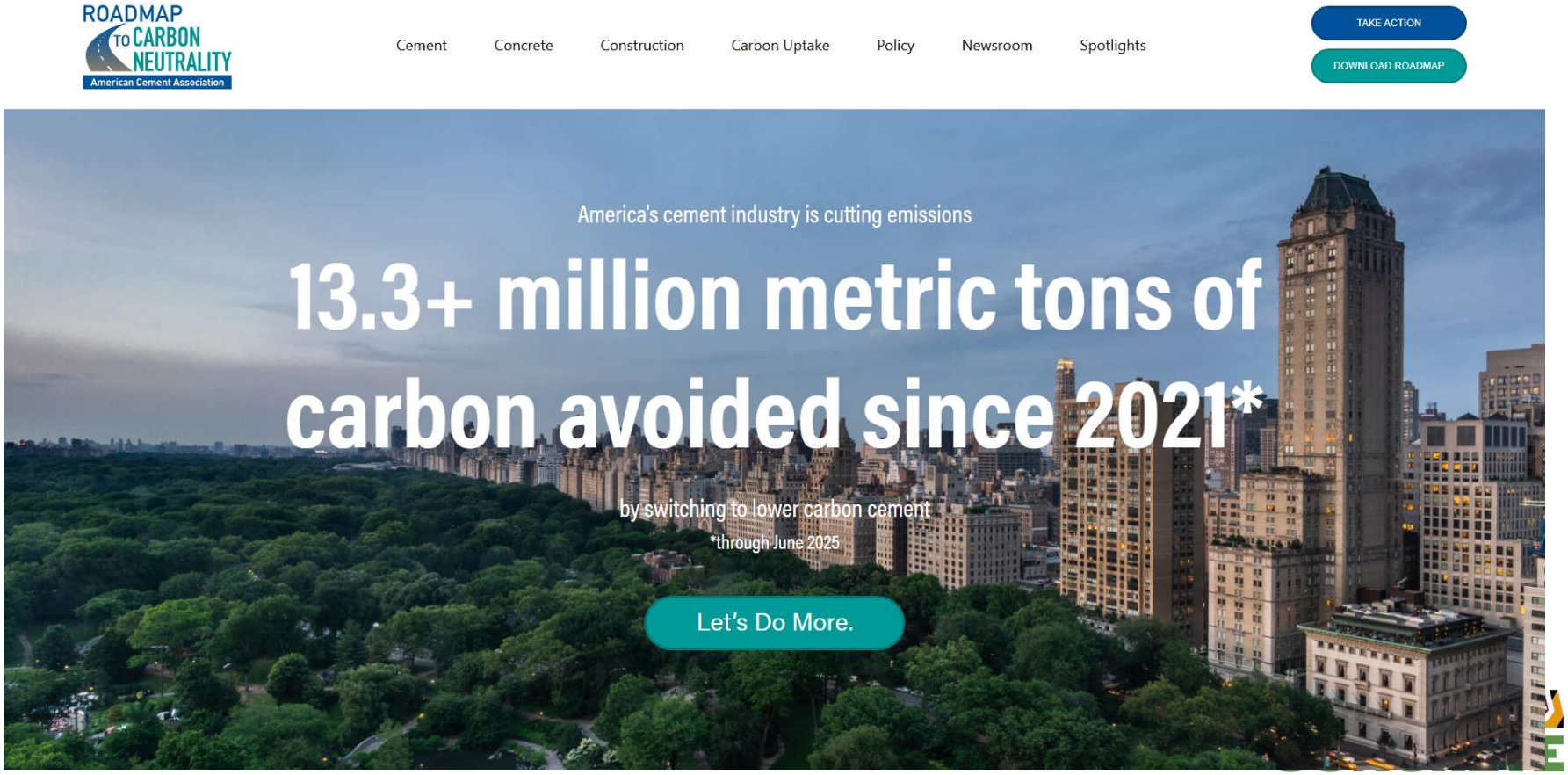
- Replace raw materials with recycled materials
- Produce low(er) carbon cement blends

Benefits

- More efficient resource use
- Lower burden on landfills
- More domestic cement production from the same amount of clinker
- Reduced reliance on imports
- More environmentally friendly products

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Impact of Implementing Blended Cements 2021-2025



Specifying Cements





- Portland Cement (ASTM C150 / AASHTO M 85)
- Blended Cements (ASTM C595 / AASHTO M 240)
- Performance specification for hydraulic cements (ASTM C1157)

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ASTM C595

- First published in 1967
- Combined ASTM C 205-58T *Standard Specification for Portland Blast-Furnace Cement,* ASTM C 340-58T *Standard Specification for Portland Pozzolan Cement*, and ASTM C 358-58 *Standard Specification for Slag Cement*
- Revised in 2006 to take on existing naming convention

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Blended Cement Nomenclature

- Type IL(X) Portland-limestone blended cement
- Type IS(X) Portland blast-furnace slag cement
- Type IP(X) Portland-pozzolan cement
- Type IT(AX)(BY) Ternary blended cement

X and Y are amounts of ingredients
A and B are types of ingredients
- P for pozzolan
- S for slag
- L for limestone

Example:
Type IL(10) ≈ 10% limestone
Type IT(P25)(L10)
≈ 25% pozzolan
≈ 10% limestone

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Blended Cement Composition

Type IL	Type IP	Type IS	Type IT	
Portland cement or clinker	Portland cement or clinker	Portland cement or clinker	Portland cement or clinker	
Limestone (5 to 15%)	Pozzolan (Up to 40%)	Slag (Up to 70% or 95%*)	2 other ingredients:	Limestone + Pozzolan
				Limestone + Slag
				2 Pozzolans
				Pozzolan + Slag

*Some specifications restrict >70% slag to non-structural applications

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Blended Cement Composition (August 2026)

<table>
<tr><th>Type IL</th><th>Type IP</th><th>Type IS</th><th colspan="2">Type IT</th></tr>
<tr><td>Portland cement or clinker</td><td>Portland cement or clinker</td><td>Portland cement or clinker</td><td colspan="2">Portland cement or clinker</td></tr>
<tr><td colspan="5">Base of clinker or portland cement or PLC (August 2026)</td></tr>
<tr><td colspan="5">Limestone up to 15% max (August 2026)</td></tr>
<tr><td rowspan="2">Limestone (5 to 15%)</td><td rowspan="2">Pozzolan (Up to 40%)</td><td rowspan="2">Slag (Up to 70% or 95%*)</td><td rowspan="2">2 other ingredients:</td><td>2 Pozzolans</td></tr>
<tr><td>Pozzolan + Slag</td></tr>
</table>

*Some specifications restrict >70% slag to non-structural applications

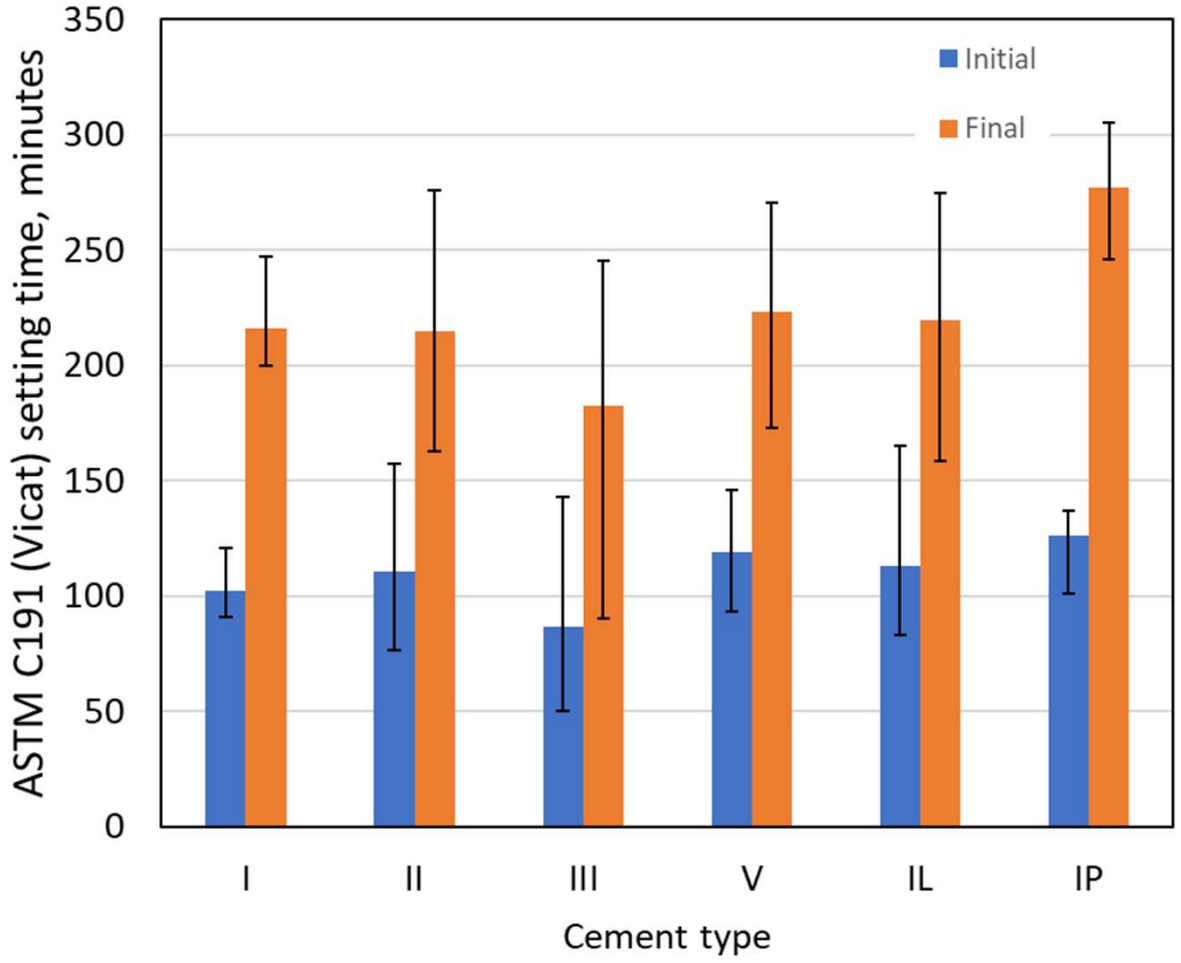
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General Physical Requirements

	Portland Cement ASTM C150/ AASTHTO M 85	Blended Cement ASTM C595/ AASHTO M 240	Performance-Based Cement ASTM C1157
	I II	IL, IP, IS, IT	GU
Setting Time (min)	45 - 375	45 - 420	45 - 420
Strength (MPa)		(varies with L-SCM content)	
3 d	12 10	13 10	13
7 d	19 17	20 17 11	20
28 d	[28 28]	25 22 21	28
Air content (NAE), %	12	12	12

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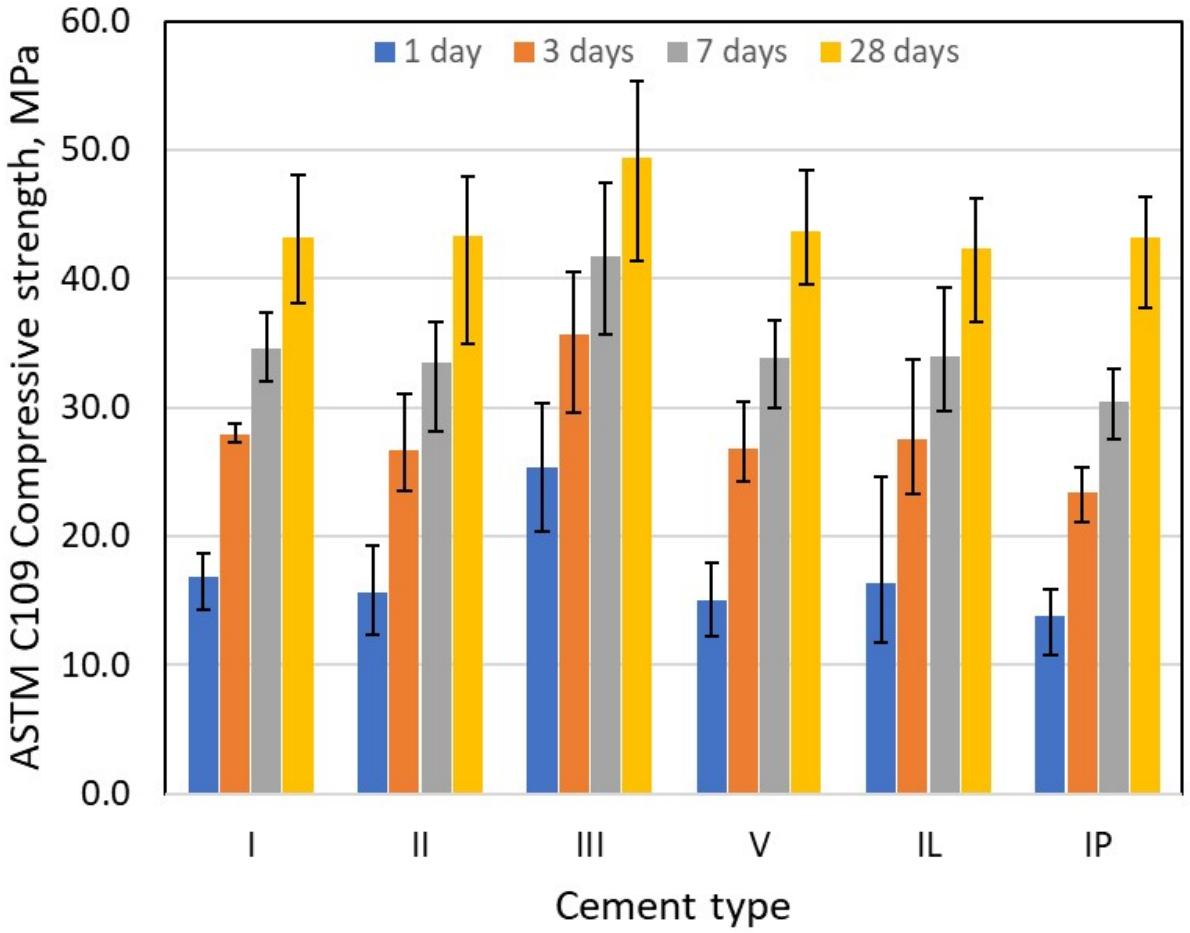
Setting time



Source: ACA SN3354

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Strength



Source: ACA SN3354

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Other Blended Cements & Performance Cements

- **Type IC**, portland-composite cement
  - *ASTM C595 in August 2026*

Type IC Composition
Base of clinker or portland cement (or PLC?)
Limestone ≤30% max
Total limestone + pozzolan + slag ≤70%

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Supplementary Cementitious Materials (SCMs)

ASTM C618 Coal Ash and Natural Pozzolans

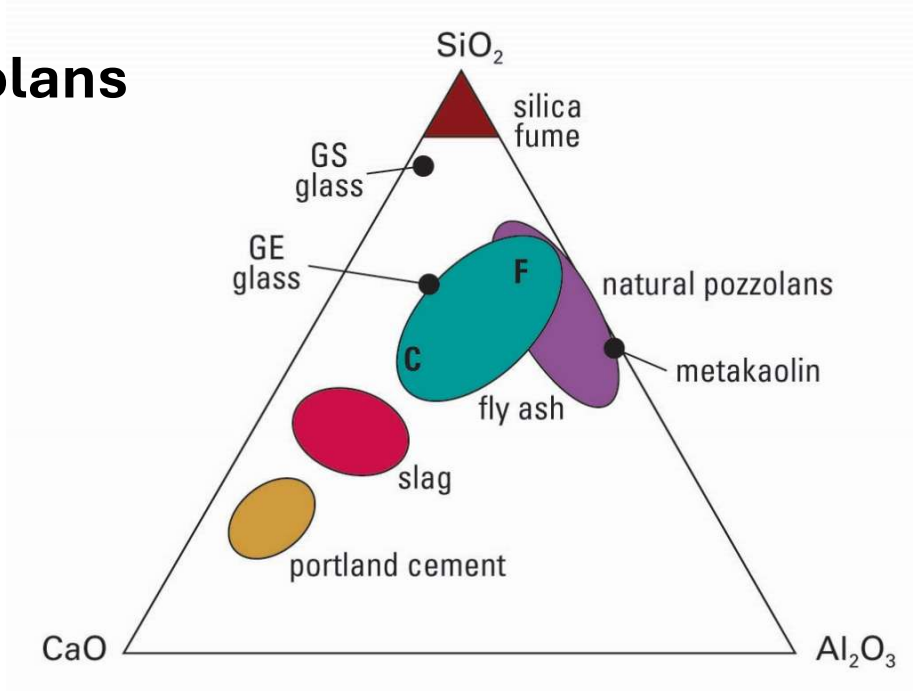
ASTM C1945 Natural Pozzolans

ASTM C989 Slag Cement

ASTM C1240 Silica Fume

ASTM C1866 Ground Glass

ASTM CXXX Performance-Based SCMs



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Beyond PLC: Other Blended Cements

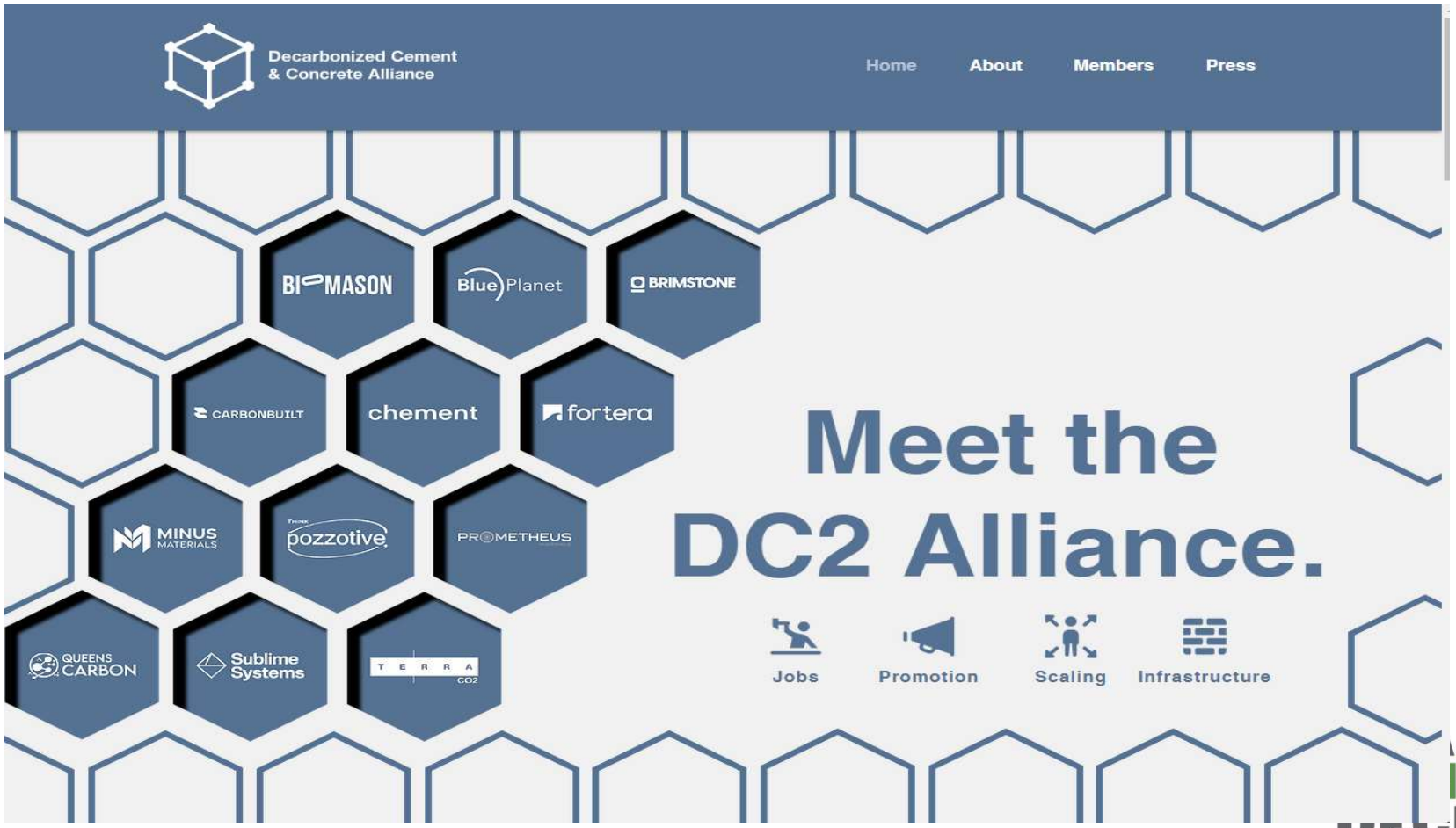
- Extensive, targeted research to support introduction of Type IL
- Why less targeted research on Types IP, IS, IT?
  - Proprietary products with a wider range of composition, so no "generic" version
  - Producers generate property & performance data during product development
- Additional data for SCM use in concrete:
  - SCMs have been added to concrete for nearly 100 years
  - Thorough understanding of SCM effects on fresh and hardened properties
  - From 2020-2024, NRMCA "average concrete mix" contains ~16.5% SCM
    - (10.7% fly ash and 5.7% slag cement)
- **Blended cements are simply another method of adding SCMs to concrete mixes**

Beyond PLC: Other Blended Cements

- Type IL is >95% of blended cements nationally
- Types IP and IS have been around for quite some time
  - Anticipate more
  - Higher reductions in CO2 footprint
  - Familiarity with SCMs
- Type IT has been defined since 2009
  - A few in the US market
- Type IC: Newly defined

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Alternative Cementitious Materials

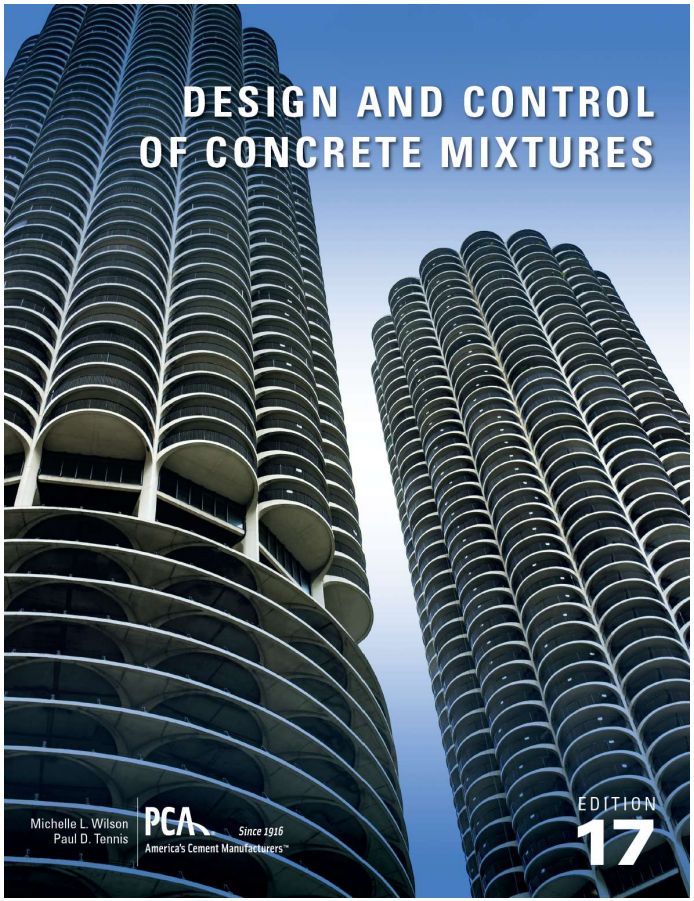


Education

- Industry Conferences- WOC, ACI, ASTM, ConcreteWorks etc.
- Regional Workshops
- Resources- Reports, Tech Sheets, Checklists
- Cement Plant Tours
- Blended Cement Workshops
  - May 12 Boston
  - May 15 Kansas City
  - May 20 Charlotte



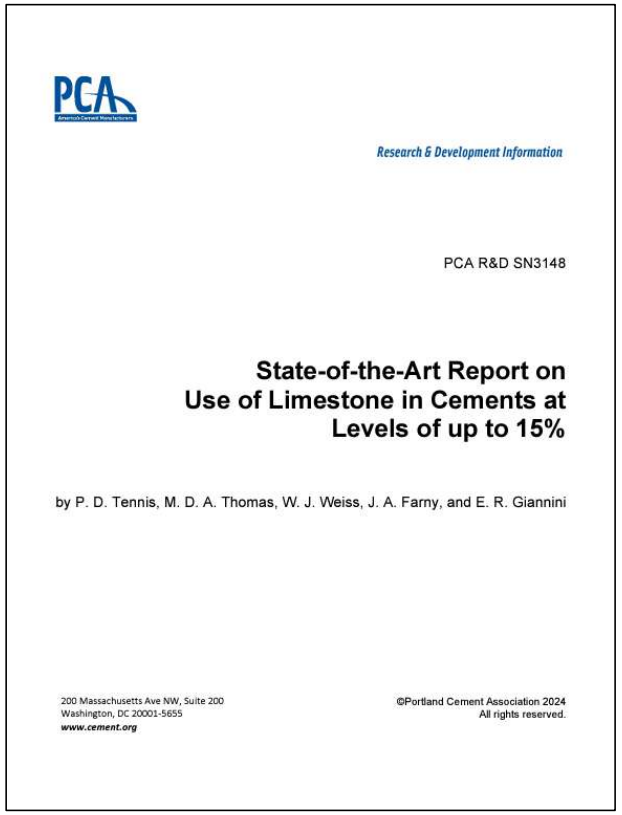
Reference Literature



- *Wilson, Michelle L. and Tennis, Paul D., Design and Control of Concrete Mixtures, EB001, 17th edition, Portland Cement Association, Skokie, Illinois, USA, 2021, 600 pages.*

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State of the Art Report on PLC



PCA

Research & Development Information

PCA R&D SN3148

State-of-the-Art Report on Use of Limestone in Cements at Levels of up to 15%

by P. D. Tennis, M. D. A. Thomas, W. J. Weiss, J. A. Farny, and E. R. Giannini

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Washington, DC 20001-5655
www.cement.org

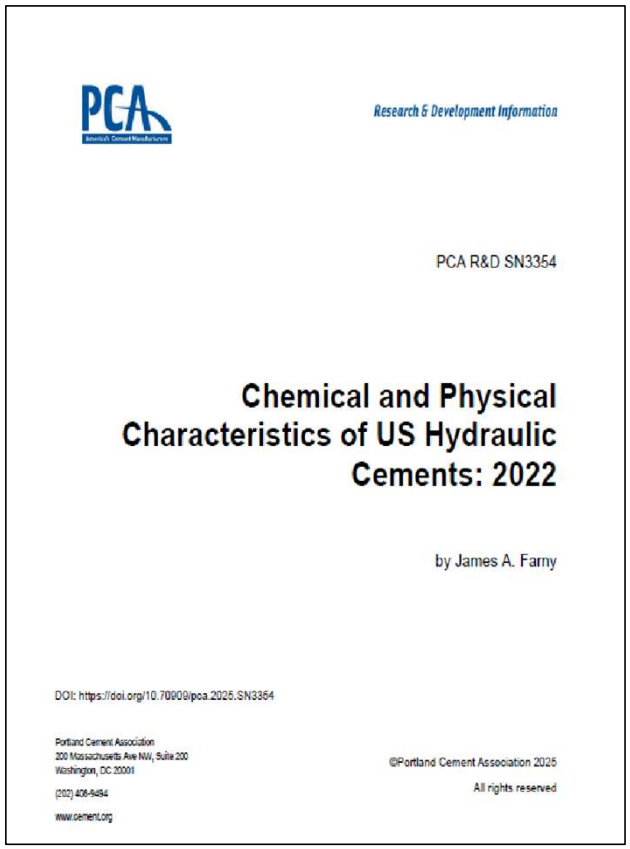
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PCA SN3148, 2024

- Workability, bleeding, placing and finishing
- Setting time, hydration, HOH
- Strength, strength development
- Deicer scaling, freeze-thaw resistance
- Chloride permeability
- ASR resistance
- Sulfate resistance
- Abrasion resistance

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Chemical and Physical Characteristics of US Hydraulic Cements: 2022


PCA

Research & Development Information

PCA R&D SN3354

Chemical and Physical Characteristics of US Hydraulic Cements: 2022

by James A. Farny

DOI: https://doi.org/10.70909/pca.2025.SN3354

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PCA SN3354, 2025

- 2022 Survey Responses
- 60% of market represented
- 47 Type IL cements reported
  - About 14% of cement shipments by volume, USGS data
  - Portland Cements
  - Blended Cements

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Why Bogue Phase Estimates Are Not Applicable for Blended Cements



CEMENT TECHNOLOGY

Why Bogue Phase Estimates Are Not Applicable for Blended Cements

Introduction

The purpose of this paper is to explain why potential cement phase compositions (C_3S, C_2S, C_3A, and C_4AF) are not calculated and reported using the Bogue equations for ASTM C595/AASHTO M 240 blended hydraulic cements.

The Bogue equations were developed in the 1920s to provide estimates of the amounts of potential phases that may be present in portland cement clinker and cements based on the oxide chemistry of portland cement clinker, correcting for calcium sulfate additions, such as gypsum. In 2005, ASTM C150 and AASHTO M 85 added adjustments to the Bogue equations for the purpose of reporting phase compositions of portland cement, which can contain up to 5% each of limestone and/or an inorganic processing addition (IPA). ASTM C595 and AASHTO M 240 do not contain instructions for the use of Bogue equations for blended cements because the presence of limestone, gypsum, IPAs, and SCMs make those estimates irrelevant and inaccurate.

Bogue equations are formulas for estimating portland cement phase composition, using oxides (CaO, SiO_2, Al_2O_3, Fe_2O_3) of elemental analysis. Because thermodynamic equilibrium may not be reached during clinkering in the kiln, and other assumptions inherent to these formulas, calculated phase compositions only approximately describe a portland cement. In blended cements, not all constituents are processed in a kiln. Applying Bogue equations to the oxide composition of a finished blended cement to calculate clinker phases is fundamentally incorrect. The oxides for limestone, pozzolans, and slag used in blended cements are significantly different from portland cement and that can lead to analytical interferences. These interferences distort the results obtained if attempting to apply the Bogue equations to these cements and will clearly yield unrealistic values for the mineral phases. The primary utility of reporting Bogue phase composition was to satisfy requirements for a portland cement to be moderate or high sulfate-resistant (Type II(MS) or Type V), or to have lower heat of hydration cement characteristics (Type II(MH) or Type IV). ASTM C595/AASHTO M 240 takes a fundamentally different approach to establishing heat of hydration (performance testing by isothermal calorimetry, ASTM C1702) and sulfate resistance (performance testing by ASTM C1012); Bogue phases are simply not applicable and less relevant for blended cements. Pozzolans and slag cement generally improve the sulfate resistance of blended cements and reduce the early heat of hydration, so even if Bogue phases were correctly determined, they would not adequately characterize these performance characteristics of the cement. As such, there are no requirements in ASTM C595/AASHTO M 240 for Bogue phase contents of any blended cement.

The performance of ASTM C595/AASHTO M 240 cements are evaluated for end-use using month-to-month uniformity of the product and compositional information that is reported by suppliers via mill test reports and other documentation.

A few examples of applying Bogue equations to blended cements are shown in Table 1. This table shows the calculated Bogue phase compositions using a single base portland cement combined with various components to make different blended cements. The simplified method in Annex A1 of ASTM C150/AASHTO M 85 is used to adjust for the limestone, pozzolan, or slag content of the cement. In these examples, the Type IL cement is calculated to have a negative C_2S, which is not possible, as the lowest value would be zero. The Type IP and Type IS cements have higher calculated C_3A values than the base portland cement, despite each containing less clinker. Type IP and Type IS cements would typically be expected to provide higher levels of sulfate resistance, but the calculated Bogue C_3A values would indicate lower sulfate resistance. All of the Type IP examples shown also have negative C_2S values, and several have C_2S above 100%, none of which makes sense. If a phase is not present, it should have a value of zero. If only a single phase is present, it would have a maximum value of 100%, not greater than 100%. These examples demonstrate that the Bogue calculations are not meaningful for blended cements.

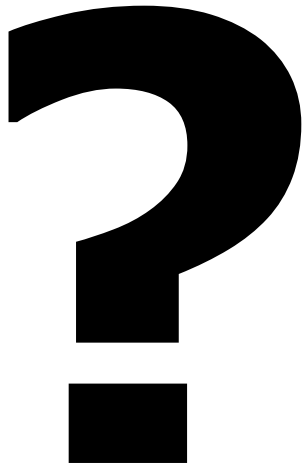
PCA Information Sheet IS791.02
doi: https://doi.org/10.20909/pca.2024.IS791.02

PCA IS791, 2024

- Analytical interferences from oxides in ingredients
- Nonsensical results

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Questions and Further Information



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