Ground Glass Pozzolans

A proven and cost-effective low-carbon, high-performance solution for concrete

THINK pozzotive

Urban Mining Industries produces Pozzotive®, a ground glass cement replacement made from post-consumer glass. It is a proven, safer, sustainable and higher-performing material that dramatically reduces embodied CO_2 emissions in concrete

O&G Industries is Connecticut's largest privately-held construction company and one of the Northeast's leading providers of construction services and products. The company owns and operates a network of ready-mix concrete and asphalt plants, quarries, and supply yards

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Halletts Point, the first high-rise built with a ground glass pozzolan in the concrete mix

What's a Pozzolan?

- A pozzolan is a fine powder that, by itself, is not cementitious but, when mixed with water and portland cement, becomes cementitious.
- Pozzolans are essential to making stronger and more durable high-performance concrete.
- Ground Glass Pozzolans (GGP) not only create a low-carbon, high-performance concrete, they solve the challenge of what to do with our nation's unwanted recycled glass.

How does it work?

- When cement hydrates in a concrete mixture with aggregates:
- Calcium-silicate-hydrate (C-S-H or the good stuff) is formed. It's what binds the overall concrete mix.
- Calcium hydroxide (CH or the bad stuff) is also formed. It weakens the concrete and causes porosity.
- Pozzolans react with deleterious CH, converting it to additional beneficial C-S-H, by giving up a silica atom and creating stronger and more durable concrete. Glass is about 72% SiO_2.

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The Ongoing Glass Challenge

- **8M+ tons** of non-degradable post-consumer glass is sent to landfills every year in the U.S.
- **Only about a third of glass is recycled** in the U.S. The majority is redemption glass.
- **Single stream recycling in the US is the most convenient for consumers but more challenging for processors.** Bottle manufacturers require a minimum size for color segregation and ceramics and porcelains removed from comingled collections.
- Many times, **transporting the heavy, low value commodity beyond its metro area is cost prohibitive.**

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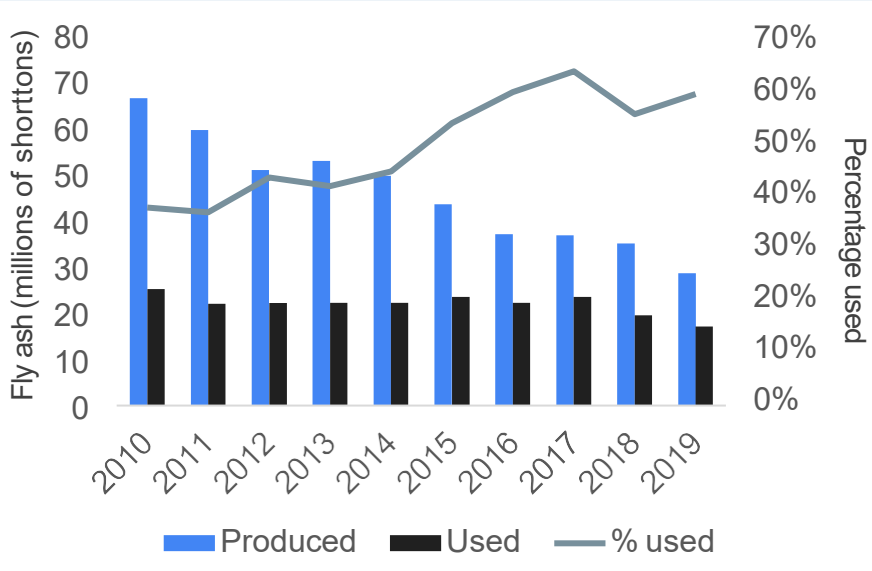
Why Now: Decline of traditional cement replacements drives demand for new and cleaner alternatives

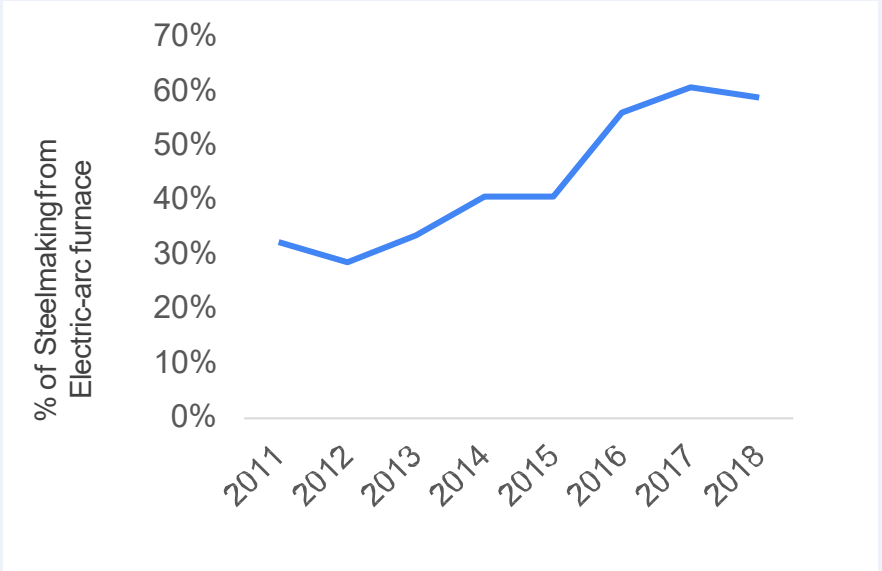
Available fly ash is steadily declining

Fly ash global production and usage



Source: American Iron and Steel Institute, 2019.

Conversions to Electric-arc furnaces are reducing the availability of slag



Source: Institute for Energy Economics and Financial Analysis, World Steel Assoc., 2020.

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Think Planet *and* Performance with Glass Pozzolans

1. Reduces CO_2 emissions by ~95%+
Low energy intensity process versus cement

2. Reduces waste
Uses post-consumer glass in any color or size and ceramics

3. Reduces "heat island" effect
Lighter material that increases reflectivity

4. Creates stronger concrete
Better performing, low-carbon concrete at no additional cost

5. Increases concrete life
5X more resistant to chloride and moisture penetration

6. Safer material
Free of crystalline silica, a carcinogen, and toxic heavy metals

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Promoting a circular economy

1. Used
Glass is valued for holding the strength, safety, aroma and flavors of products

2. Disposed
Glass and ceramic are sent to local material recovery facility

3. Transformed
Processed glass and ceramic is used to produce Pozzotive®

4. Reused
Up to 50% of cement is replaced with Pozzotive® in concrete

THINK pozzotive®

Cement/Concrete in America

- What's the difference between the two?
- The US uses over 100 mm tons of cement a year.
- Concrete usage worldwide, ton for ton, is twice that of steel, wood, plastics, and aluminum combined.
- It's critical for the rebuilding of American infrastructure and is by far the most disaster-resilient material.
- Longer lasting materials = less maintenance. It is non-combustible, and does not rot, warp or mold.
- High-performance concrete typically requires supplemental cementitious materials –historically, Fly Ash, and to a lesser extent -silica fume and metakaolin.
- But concrete does have its environmental challenges.

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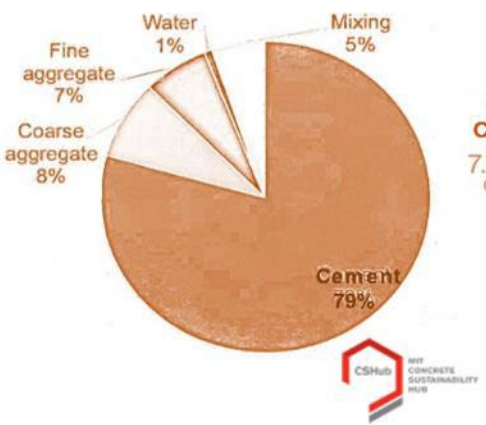
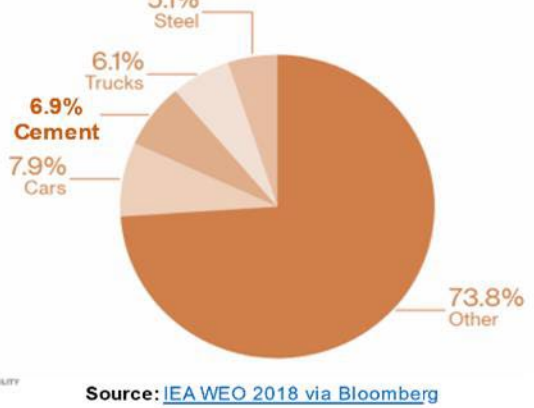
Cement's disproportionate impact in concrete



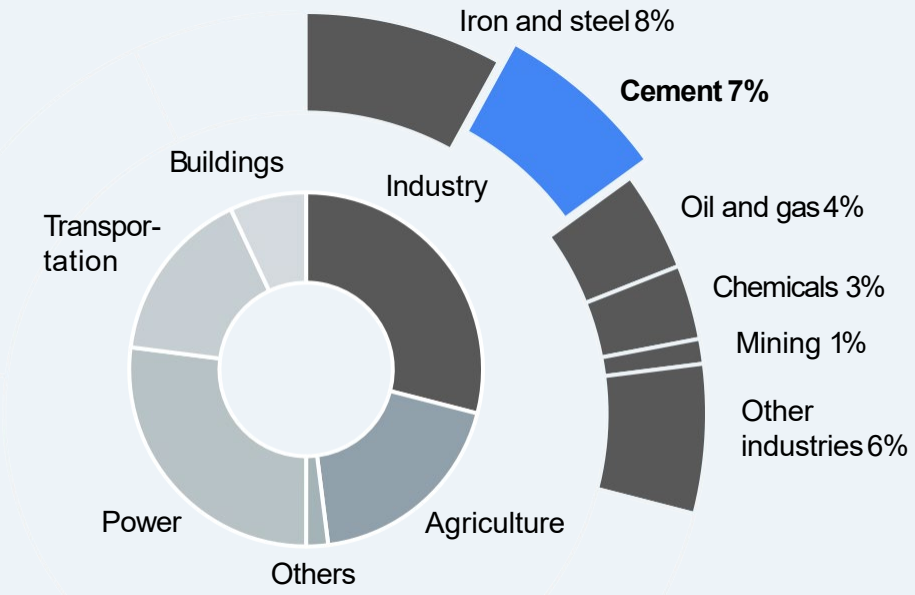


Source: IEA WEO 2018 via Bloomberg

The cement and concrete industries need new and affordable technologies to fight climate change

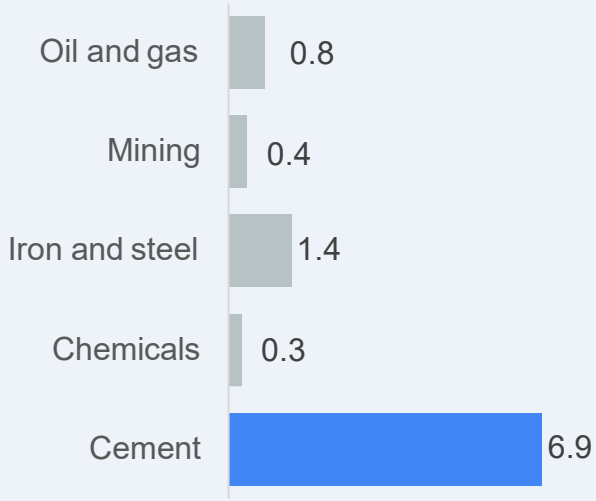
Cement is one of the largest CO_2 emitters

Share of global CO_2 emissions



Cement generates the most CO_2 per $ of revenue

Kg of CO_2 per $ of product sales



Source: McKinsey – Laying out the foundation for zero carbon cement.

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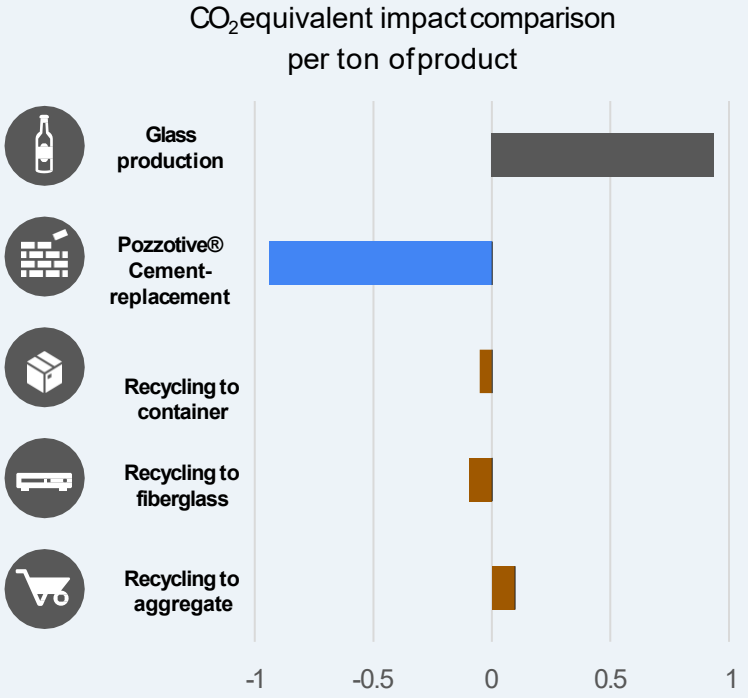
The positive climate impact of glass-to-concrete is over 5x the alternatives



Source: Oregon Department of Environmental Quality.

12+ M

tons of glass is generated annually in the US

GHG potential reduction

2 M tons

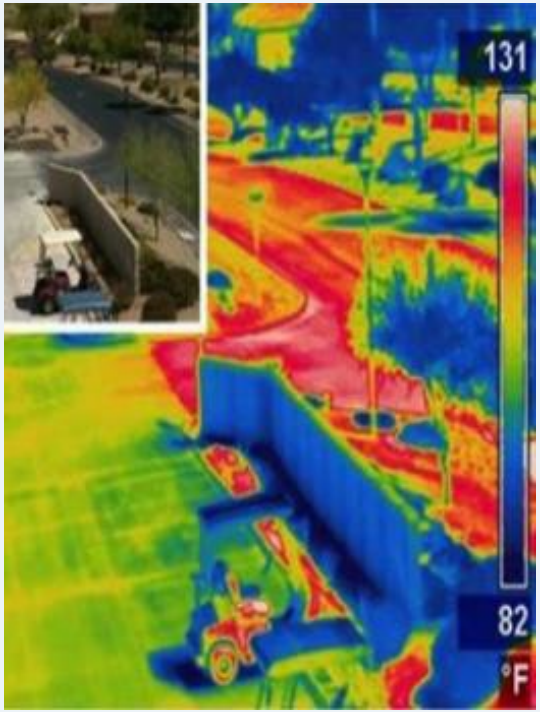
If all back to bottles

11+ M tons

if all is used for Pozzotive®

pozzotive

Lighter color significantly reduces the heat island effect



- The lighter color of Pozzotive® **reduces the harmful urban Heat Island effect** by reducing air temperatures
- **Building operations generate 3x more emissions** than construction
- Creating cool white rooftops, floors and building surfaces lower energy use in buildingsby **reducing both cooling and lighting needs**

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42% reduction in concrete's carbon footprint

Cradle to Gate GWP (kg CO2e) per cubic yard of a 9,000 psi mix design with and without Pozzotive®

Material	Units	Quantity/Cubic Yard	
		W/out Pozzotive	With Pozzotive
Type I/II Cement	lb	850	425
Pozzotive	lb	-	425
Sand	lb	1,150	1,150
Stone 1	lb	1,000	1,000
Stone 2	lb	700	700
Water	Gal	34.7	34.7
Admix1	fl.oz	46.8	46.8
Admix2	fl.oz	17.0	17.0
Admix3	fl.oz	25.5	25.5
GWP (kg CO2e)		**625.0**	**361.0**
28-day break (psi)			**9,623**
56-day break (psi)			**12,852**

A 50% replacement of cement in a 9,000-psi concrete mix design yielded a 42% reduction in the concrete carbon footprint.

The 28-day break was 9,623 psi and the 56-day break was 12,852 – outstanding strength performance

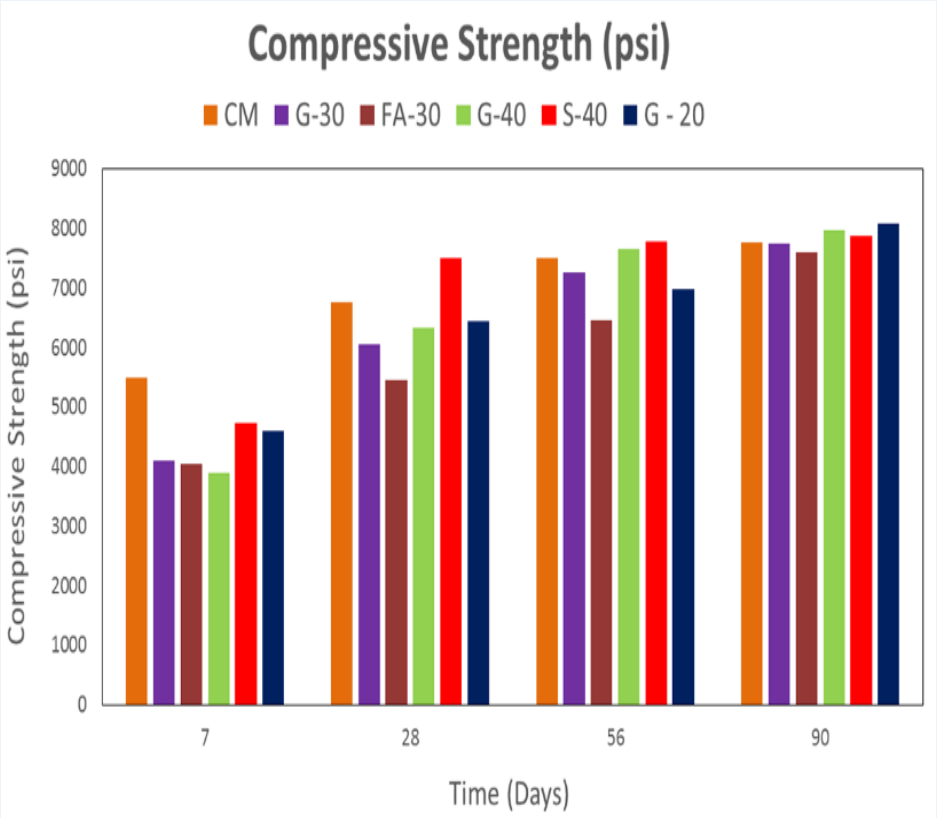
THINK pozzotive®

The protection against Chloride is more than 5x that of cement-only concrete

Rapid Chloride Permeability Test (ASTM C1202)

Concrete Mix	Coulombs
Cement only	1,617
40% of cement replaced with slag	1,100
30% of cement replaced with fly ash	500
20% of cement replaced with Pozzotive	456
30% of cement replaced with Pozzotive	436
40% of cement replaced with Pozzotive	282

Impressive compressive strengths through and beyond 90 days



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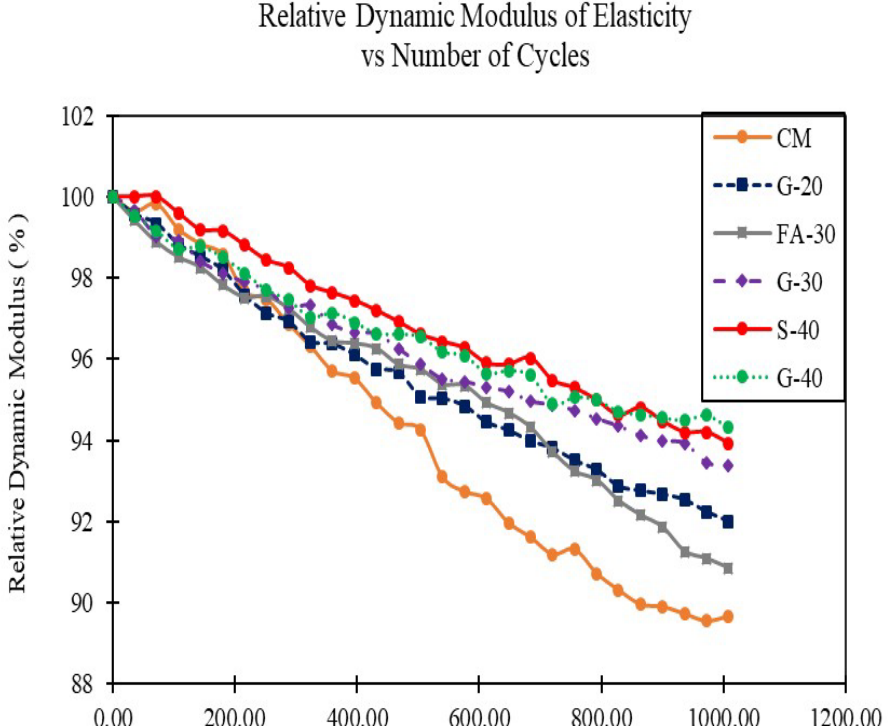
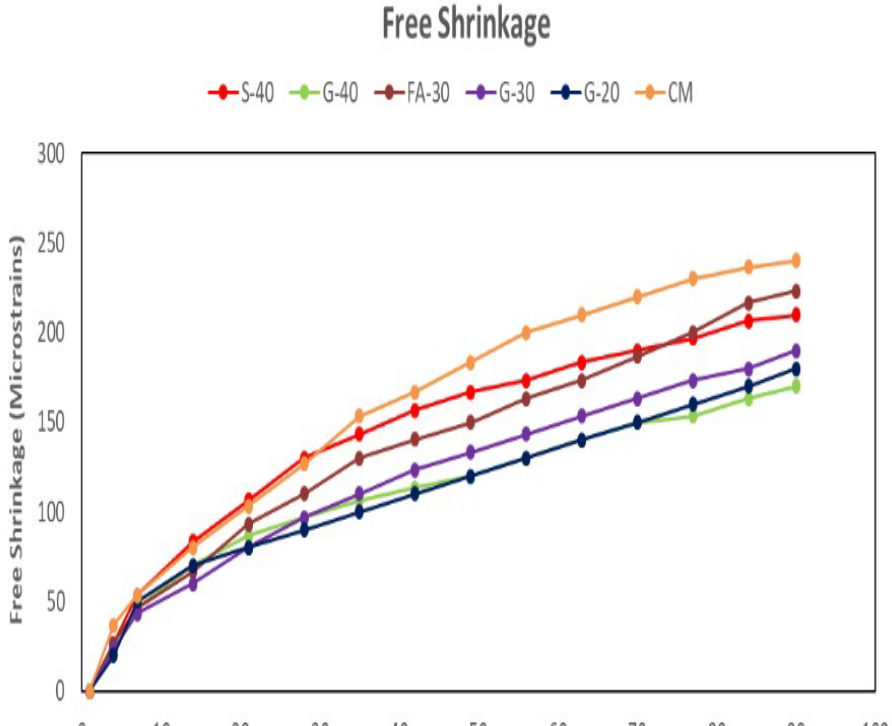
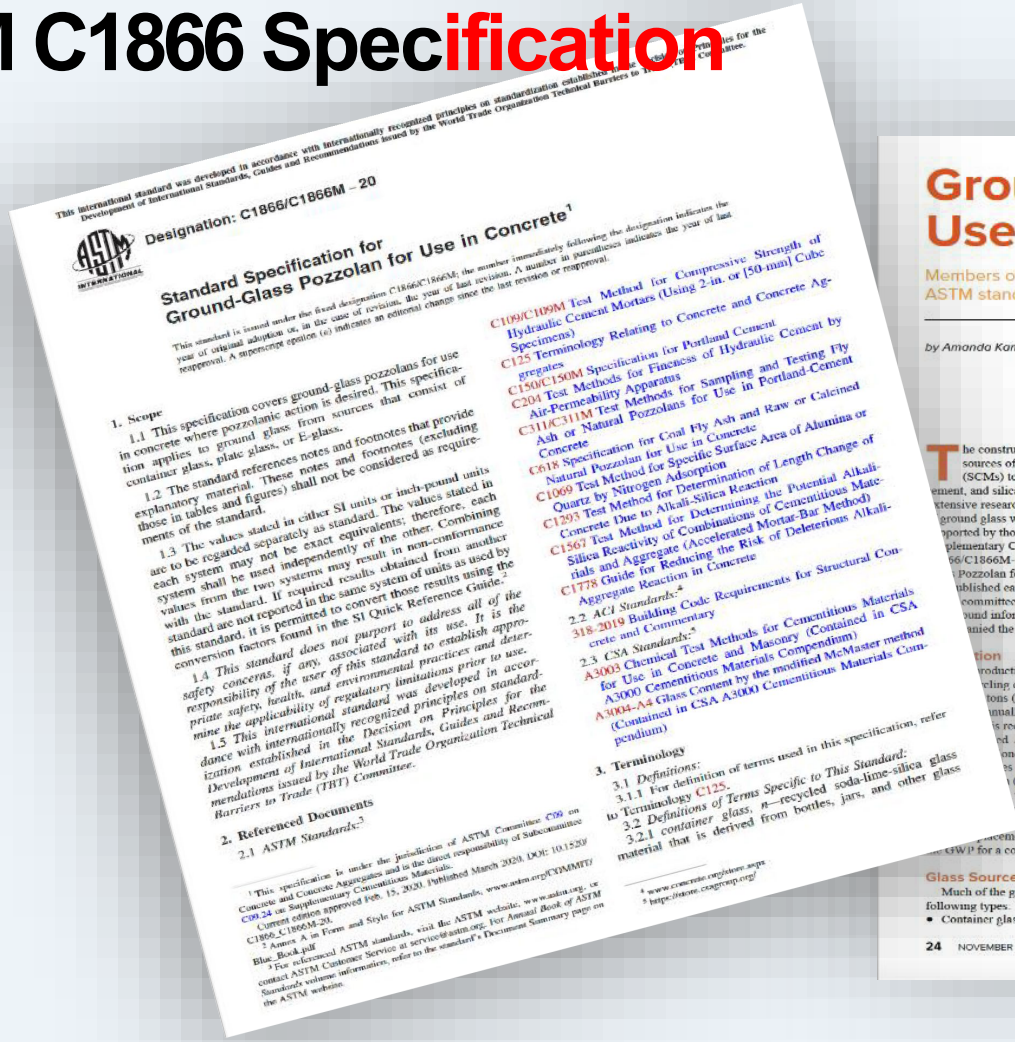
After 1,000 freeze-thaw cycles, mass loss was less than 1%; no visible cracks or scaling;

GGP mixes significantly reduced concrete shrinkage vs. mixes with cement only, fly ash and slag





ASTM C1866 Specification



This international standard was developed in accordance with internationally recognized principles on standardization established in the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: C1866/C1866M – 20

Standard Specification for Ground-Glass Pozzolan for Use in Concrete[1]

This standard is issued under the fixed designation C1866/C1866M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers ground-glass pozzolans for use in concrete where pozzolanic action is desired. This specification applies to ground glass from sources that consist of container glass, plate glass, or E-glass.

1.2 The standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. If required results obtained from another standard are not reported in the same system of units as used by this standard, it is permitted to convert those results using the conversion factors found in the SI Quick Reference Guide.[2]

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C125 Terminology Relating to Concrete and Concrete Aggregates

C150/C150M Specification for Portland Cement

C204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus

C311/C311M Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete

C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C1069 Test Method for Specific Surface Area of Alumina or Quartz by Nitrogen Adsorption

C1293 Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction

C1567 Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)

C1778 Guide for Reducing the Risk of Deleterious Alkali-Aggregate Reaction in Concrete

2.2 *ACI Standards:*[4]

318-2019 Building Code Requirements for Structural Concrete and Commentary

2.3 *CSA Standards:*[5]

A3003 Chemical Test Methods for Cementitious Materials for Use in Concrete and Masonry (Contained in CSA A3000 Cementitious Materials Compendium)

A3003-A4 Glass Content by the modified McMaster method (Contained in CSA A3000 Cementitious Materials Compendium)

3. Terminology

3.1 *Definitions:*

3.1.1 For definition of terms used in this specification, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *container glass, n*—recycled soda-lime-silica glass material that is derived from bottles, jars, and other glass

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.24 on Supplementary Cementitious Materials.

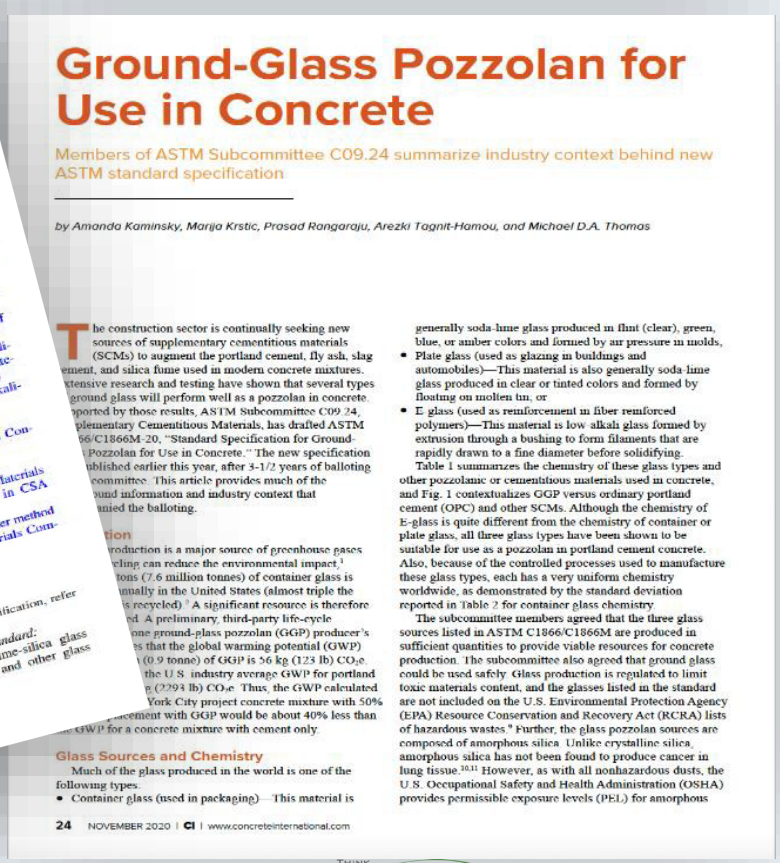
Current edition approved Feb. 15, 2020. Published March 2020. DOI: 10.1520/C1866_C1866M-20.

[2] Annex A in Form and Style for ASTM Standards, www.astm.org/FORMMTG/Blue_Book.pdf

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

[4] www.concrete.org/store.aspx

[5] https://store.csagroup.org/



Ground-Glass Pozzolan for Use in Concrete

Members of ASTM Subcommittee C09.24 summarize industry context behind new ASTM standard specification

by Amanda Kaminsky, Marija Krstic, Prasad Rangaraju, Arezki Tagnit-Hamou, and Michael D.A. Thomas

The construction sector is continually seeking new sources of supplementary cementitious materials (SCMs) to augment the portland cement, fly ash, slag cement, and silica fume used in modern concrete mixtures. Extensive research and testing have shown that several types of ground glass will perform well as a pozzolan in concrete. Supported by those results, ASTM Subcommittee C09.24, Supplementary Cementitious Materials, has drafted ASTM C1866/C1866M-20, "Standard Specification for Ground-Glass Pozzolan for Use in Concrete." The new specification was published earlier this year, after 3-1/2 years of balloting in the committee. This article provides much of the background information and industry context that accompanied the balloting.

- Container glass (used in packaging)—This material is generally soda-lime glass produced in flint (clear), green, blue, or amber colors and formed by air pressure in molds,
- Plate glass (used as glazing in buildings and automobiles)—This material is also generally soda-lime glass produced in clear or tinted colors and formed by floating on molten tin, or
- E glass (used as reinforcement in fiber reinforced polymers)—This material is low alkali glass formed by extrusion through a bushing to form filaments that are rapidly drawn to a fine diameter before solidifying.

Table 1 summarizes the chemistry of these glass types and other pozzolanic or cementitious materials used in concrete, and Fig. 1 contextualizes GGP versus ordinary portland cement (OPC) and other SCMs. Although the chemistry of E-glass is quite different from the chemistry of container or plate glass, all three glass types have been shown to be suitable for use as a pozzolan in portland cement concrete. Also, because of the controlled processes used to manufacture these glass types, each has a very uniform chemistry worldwide, as demonstrated by the standard deviation reported in Table 2 for container glass chemistry.

The subcommittee members agreed that the three glass sources listed in ASTM C1866/C1866M are produced in sufficient quantities to provide viable resources for concrete production. The subcommittee also agreed that ground glass could be used safely. Glass production is regulated to limit toxic materials content, and the glasses listed in the standard are not included on the U.S. Environmental Protection Agency (EPA) Resource Conservation and Recovery Act (RCRA) lists of hazardous wastes.[9] Further, the glass pozzolan sources are composed of amorphous silica. Unlike crystalline silica, amorphous silica has not been found to produce cancer in lung tissue.[10,11] However, as with all nonhazardous dusts, the U.S. Occupational Safety and Health Administration (OSHA) provides permissible exposure levels (PEL) for amorphous

Glass Sources and Chemistry

Much of the glass produced in the world is one of the following types:

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Pozzotive® GGP used across a wide range of applications

More than 120,000 yd^3 of cast-in-place concrete including the first ever high-rise structural pour

10 million+ architectural and structural concrete masonry units

500,000 ft^2 of pre-stressed concrete planks

Nearly 750,000 ft^2 of pavers

Local Glass Back To Local, Low Carbon Projects

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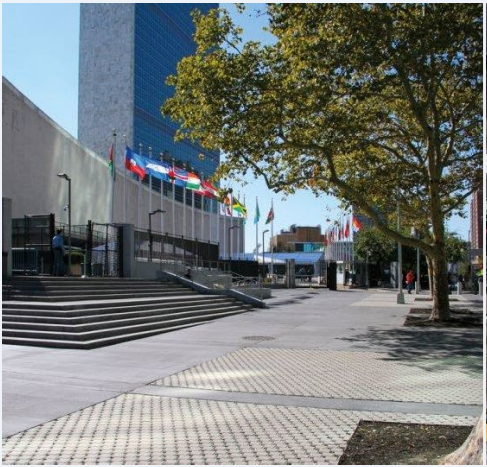
Select flagship applications of a Ground Glass Pozzolan



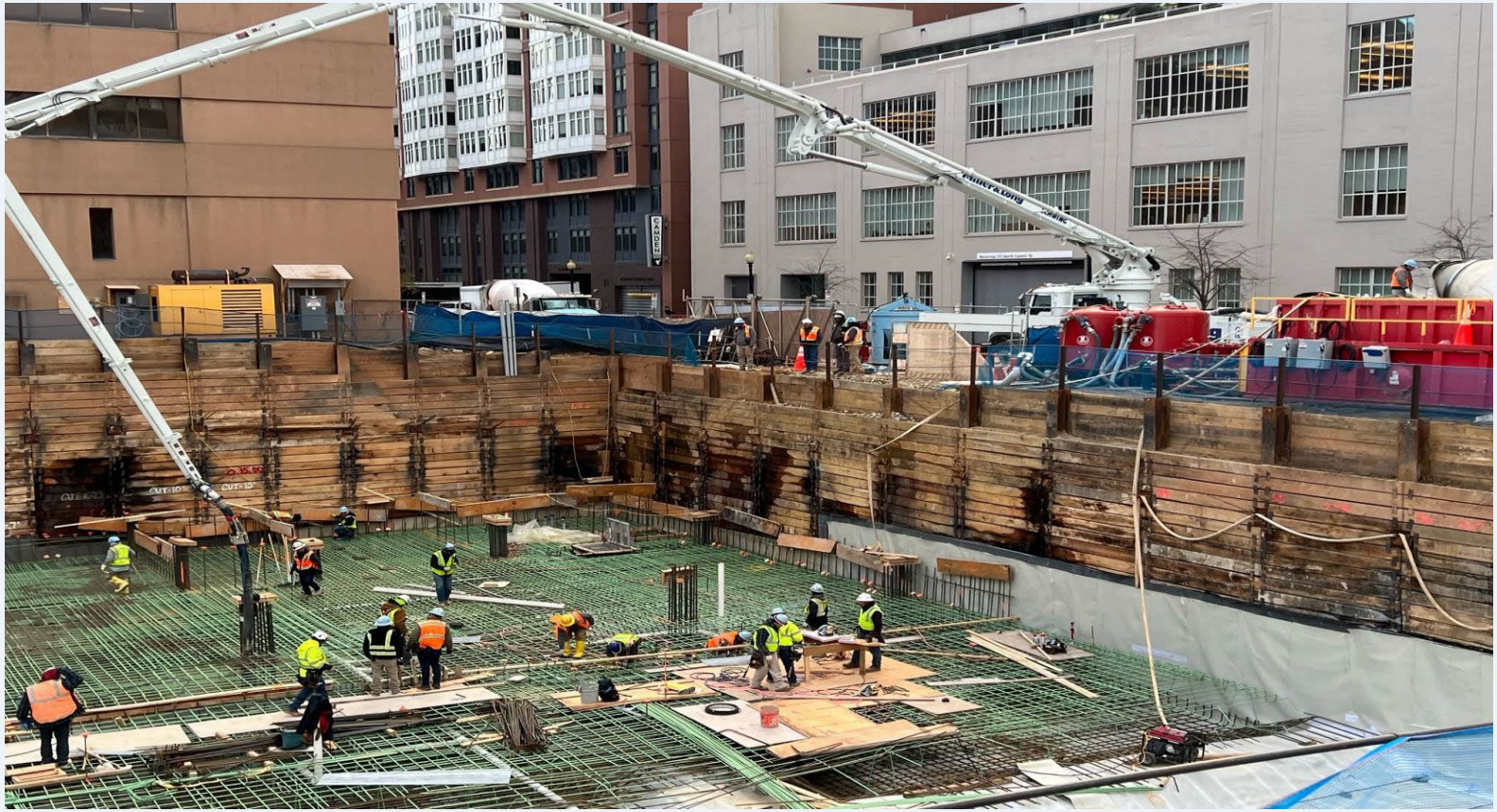
Construction
United Nations Plaza – New York, NY
Application
Pavers and Architectural CMU made from 60 tons of windows glass harvested from the UN General Assembly Building specified by diDomenico + Partners
GGP utilized
60 tons in UN Plaza + other projects
Total CO_2 savings
57 tons

Construction
2nd Ave Subway – New York, NY
Application
30% GGP replacement in CMU for construction of every station on the subway line specified by AECOM
GGP utilized
1,050 tons
Total CO_2 savings
998 tons

Construction
New headquarters for JPMorgan Chase – 270 Park Ave, New York, NY
Application
40%+ GGP replacement in building floor slabs and CMU specified by Severerud Associates
GGP utilized
5,375 tons
Total CO_2 savings
5,106 tons

Construction
Halletts Point + Halletts Point 20-30
Application
50% GGP replacement in structural concrete specified by Severerud Associates
GGP utilized
7,000 tons
Total CO_2 savings
6,650 tons

Providing Low Carbon Concrete Solutions Nationally



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Why GGP Pozzolans Now?

- Urgency to significantly reduce GHG emissions from the manufacturing of cement and to better use waste glass
- New ASTM standard makes it easier to specify Pozzotive®
- Diminishing supply of primary historic alternatives, i.e. fly ash and slag while demand and prices increase
- Contributing broadly to Envision & LEED certification

What Can *You* Do?

- Keep glass in your collection streams and keep track of it!
- Specify high-performance, low-carbon concrete and concrete-based products using a ground glass pozzolan for new projects in our towns and communities to:
  - Help solve the challenges of waste glass;
  - Significantly reduce the carbon footprint of concrete while enhance its performance
  - Extend the life of our nation's infrastructure.

THINK pozzotive®

Thank you!

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