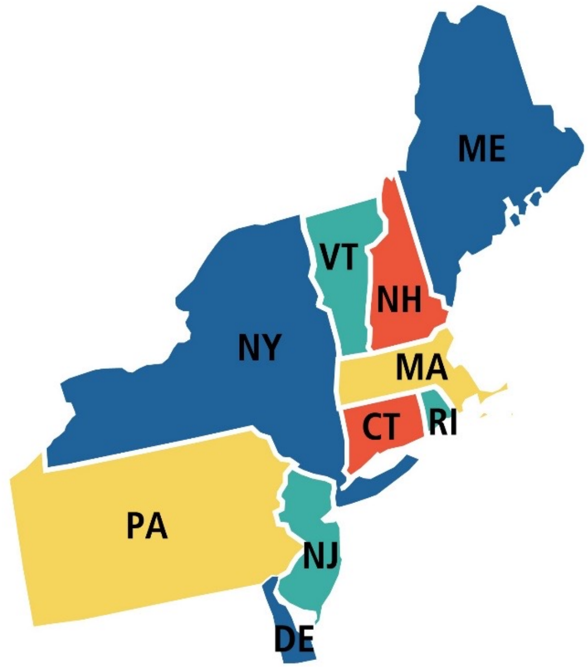
NESMEA



October 15, 2024

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EUCLID CHEMICAL

Supplementary Cementitious Materials

Pozzolanic Reaction

- When portland cement hydrates in a concrete mixture, several reaction products are produced in the concrete pore solution including:
    - Calcium-silicate-hydrate (C-S-H) – this is the primary binder of the coarse and fine aggregates that forms a hard cementitious product (i.e., concrete). GLUE
    - Calcium hydroxide (CH) – this is deleterious to the concrete matrix by weakening it and causing porosity. (eventually efflorescence)

SCM’s -Supplementary Cementitious Materials

Why SCMs - Makes better concrete

- Environmental Benefits Reduced Emissions

Cement = Calcium Silicate & Calcium Hydroxide

Calcium Hydroxide – *efflorescence*.

Cement + pozzolan (fly ash or slag or microsilica or GGP) =
more calcium silicate hydrate

Resulting in more glue in a concrete mix

Fly Ash

ASTM C618

Fly ash is fine residue

produced by the combustion of

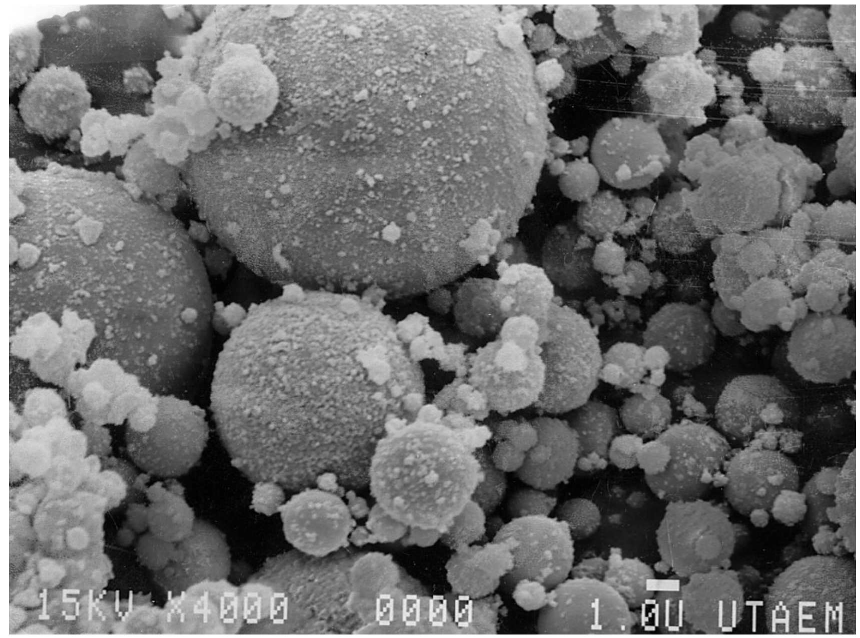
coal in coal burning power stations

Dosage Rates 10-40% for Type F Ash.
For C ash typically has higher dosages

Fly Ash

Fly ash possesses chemical characteristics similar to portland cement and aggregates.

Fly ash particles are glassy, solid or hollow, and spherical in shape.



- **Fly ash** can be a cost-effective substitute for Portland cement in many markets.
- **Fly ash** is also recognized as an environmentally friendly material because it is a byproduct and has low *embodied energy*, the measure of how much energy is consumed in producing and shipping a building material.
- By contrast, **Portland cement** has a very high embodied energy because its production requires a great deal of heat.

Other benefits for fly ash include:

- High strength gains, depending on use especially later dates
- Reduces permeability
- Increased workability
- Reduces bleeding
- Reduces heat of hydration
- Allows for a lower water-cement ratio for similar slumps when compared to no-fly-ash mixes

So why can't we get Fly Ash like we use to

*****Demand of Supply**

*****Supply and Demand**

3 reasons US coal power is disappearing

1. **Natural Gas Prices –**

Natural gas prices have decreased significantly – over 60% between 2003 and 2020

2. **The rise of renewable energy**

Solar and wind energy are now cost competitive with fossil-fueled generators, primarily because of technological advancements

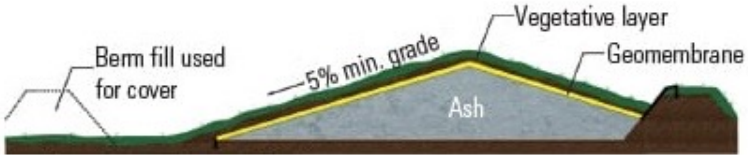
3. **Environmental regulation**

The government has instituted several environmental regulations over the past few decades aiming to reduce air pollutants emitted by the electric power sector.

Power plants and LEED

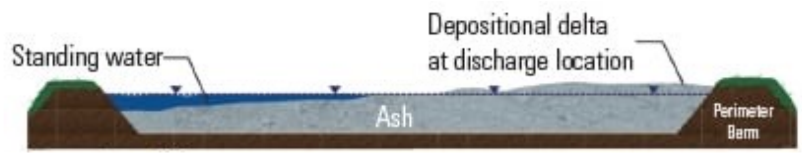
Stack

- Typically, 12-20% moisture
- Compacted in lifts
- Ash only / Fly ash Bottom Ash Blend



Pond

- Wide range of moisture up to free standing water
- Hydraulically conveyed causes striations of material
- Both Fly & Bottom Ash



Ground Granulated Blast-Furnace Slag (GGBFS)

Slag is a nonmetallic product developed simultaneously with iron in a blast-furnace, then chilled rapidly to form glassy granular particles. These granules are ground to cement fineness or finer. In concrete this slag will react with calcium hydroxides to form cementitious products.

ASTM C 989

Dosage Rates are 20-50% Higher for Mass Concrete

Slag cement should be used as a pound for pound replacement for portland cement in a concrete mixture.

Concrete Application	Slag Cement
Concrete paving	25-50%
Exterior flatwork not exposed to deicer salts	25-50%
Exterior flatwork exposed to deicer salts with w/cm $\leq$ 0.45	25-50%
Interior flatwork	25-50%
Basement floors	25-50%
Footings	30-65%
Walls & columns	25-50%
Tilt-up panels	25-50%
Pre-stressed concrete	20-50%
Pre-cast concrete	20-50%
Concrete blocks	20-50%
Concrete pavers	20-50%
High strength	25-50%
ASR mitigation	25-70%
Sulfate resistance	
Type II equivalence	25-50%
Type V equivalence	50-65%
Lower permeability	25-65%
Mass concrete	50-80%

Percentages indicate replacement for portland

For General Use

Cementitious Materials

1. Portland cement shall conform to the requirements in ASTM C-150[1] or ASTM C-1157[2].

2. Slag cement shall conform to the requirements in ASTM C-989[3].

3. Blended cement shall conform to the requirements in ASTM C-595[4].

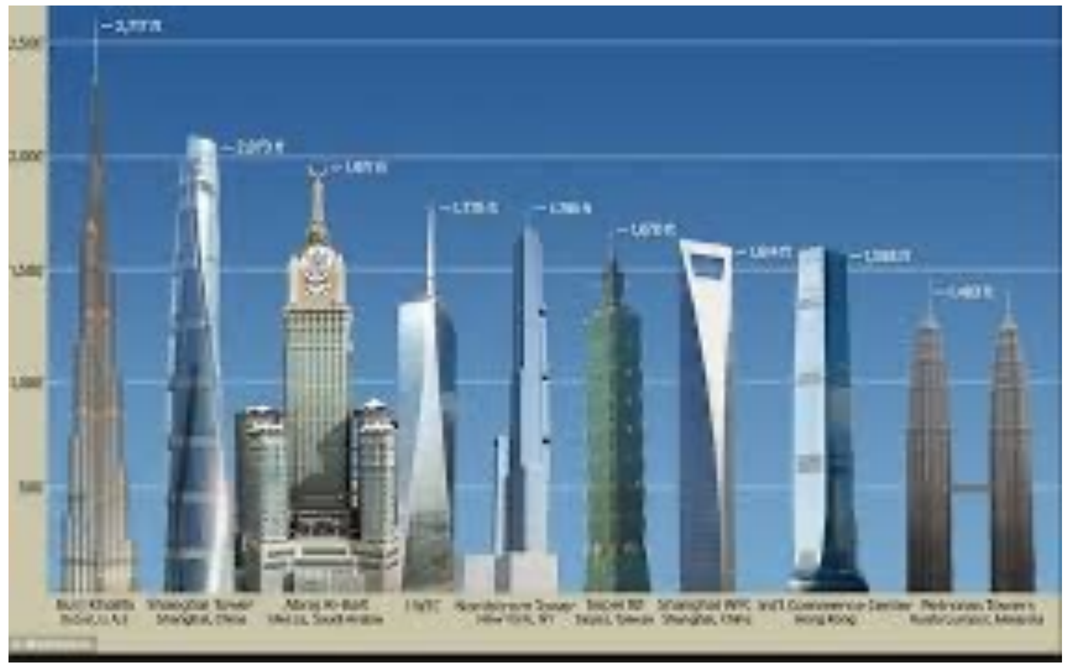
4. Pozzolans shall conform to the requirements in ASTM C-618[5].

5. Silica fume shall conform to the requirements in ASTM C-1240[6].

6. The water-cementitious materials ratio (W/CM) shall be calculated by dividing the weight of water by the weight of portland cement, plus slag cement plus pozzlans.

Other benefits for GGBFS include:

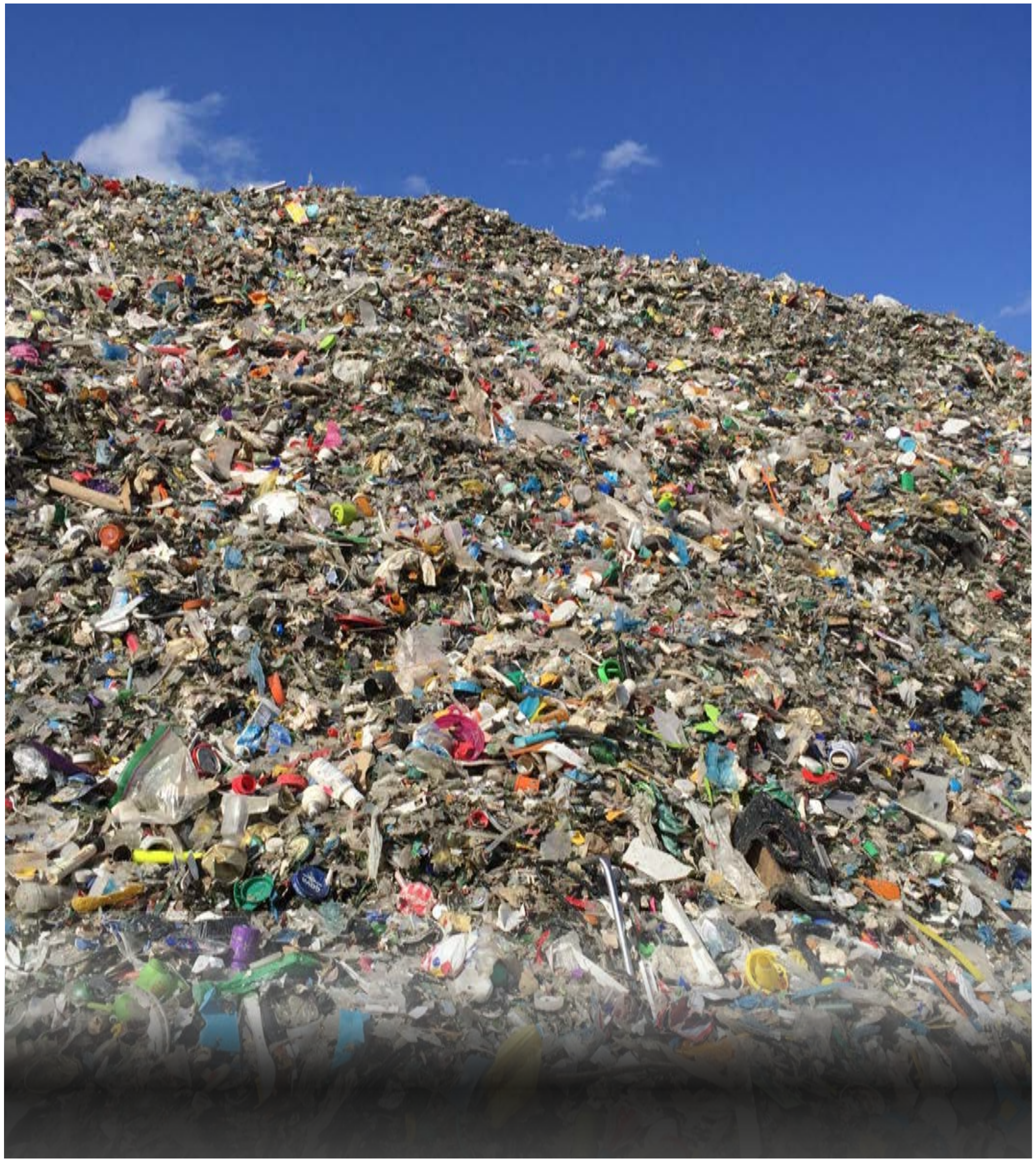
- High strength gains, depending on use
- Produces dense concrete with a smooth surface and sharp detail
- Reduces heat of hydration
- Allows for a lower water-cement ratio for similar slumps when compared to GGBFS mixes
- Reduces CO2 emissions
- Lighter in color than normal PCC
- Can help mitigate ASR
- Can be used as a system to improve Sulfate Attack



	14,000 psi @ 56 days
Cement	350 lbs
Slag	530 lbs.
Fly Ash	120 lbs.
Silica Fume	50 lbs.
Fine Aggregate	1020 lbs.
Coarse Aggregate	1250 lbs. (#57) 520 lbs. (#8)
Water	283 lbs.
HRWR Admixture , Polycarboxylate (SCC)	105oz.
Hydration Control Admixture,	40 oz.
Viscosity Modifying Admixture,	40 oz.
Air Detaining Admixture,	4 oz.
Air Content	2% +/-
Spread	26" +/- 2"
W/cm	0.27
Unit Wt. (pcf)	151.8

Ground Granulated Glass

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



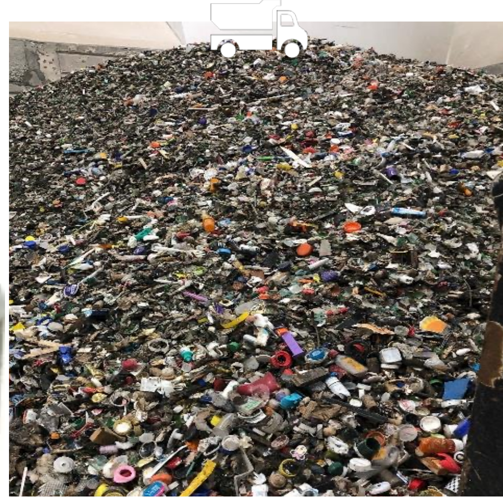
The Ongoing Glass Challenge

- **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.**

Promoting a circular economy

We Take This Locally *Manufacture This Locally* *To Build These*

Locally



Performance of GGP in Hardened Concrete

GGP not only makes concrete sustainable and easy to work with, but it also creates a higher performing, longer lasting concrete with the following attributes.

- A dramatic reduction of in the carbon footprint
- Improved adhesion of the aggregates to the cement paste – creating a stronger paste
- GGP is a white pozzolan that can be used with white and gray cement and to increase surface reflectivity and reduce urban heat island effect.
- Regionally made from post-consumer glass, both contributing to LEED and Envision accreditation
- Can be used in high performance mixes to reduce permeability or increase compressive strengths

Why Ground Glass Pozzolan Now?

- Years of proven performance
- 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 [redacted]
- Diminishing supply of primary historic alternatives, i.e. fly ash and slag while demand and prices increase
- Health/Equity Benefits of reducing urban heat island effect while avoiding heavy metals
- 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:
  - Significantly reduce the carbon footprint of concrete while enhancing its performance;
  - Help solve the challenges of waste glass;
  - Extend the life of our nation's infrastructure.

[redacted]

Contributing to Envision & LEED Certification

Institute for Sustainable Infrastructure

Materials
RA1.1 Reduce Net Embodied Energy
RA1.3 Use Recycled Materials
RA1.4 Use Regional Materials
RA1.5 Divert Waste From Landfills

Energy
RA2.1 Reduce Energy Consumption

Emissions
CR1.1 Reduce Greenhouse Gas Emissions
CR1.2 Reduce Air Pollutant Emissions

Resilience
CR2.5 Manage Heat Island Effects

ASTM C1866 Specification

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.

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)
A3004-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/COMMIT/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 by the committee. This article provides much of the background information and industry context that accompanied the balloting.

Motivation

Glass production is a major source of greenhouse gases. While recycling can reduce the environmental impact,[1] 8.4 million tons (7.6 million tonnes) of container glass is landfilled annually in the United States (almost triple the amount that is recycled).[2] A significant resource is therefore being discarded. A preliminary, third-party life-cycle assessment of one ground-glass pozzolan (GGP) producer's output[3] indicates that the global warming potential (GWP) impact for 1 ton (0.9 tonne) of GGP is 56 kg (123 lb) CO_2e. For comparison, the U.S. industry average GWP for portland cement is 1040 kg (2293 lb) CO_2e. Thus, the GWP calculated for a recent New York City project concrete mixture with 50% cement replacement with GGP would be about 40% less than the GWP for a concrete mixture with cement only.

Glass Sources and Chemistry

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

- 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

Tests for GGP

- ASTM C 157 Shrinkage
- ASTM C 666 Freeze Thaw Resistance
- ASTM C 1202 Rapid Chloride Permeability
- AASHTO T358 Surface Resistivity

Local Glass Back To Local, Low-Carbon Projects


DeCicco & Sons Market, Edge-On-Hudson, NY


New Canaan Library, CT

Ox Ridge Elementary School, CT


DEEP Western District Headquarters, CT

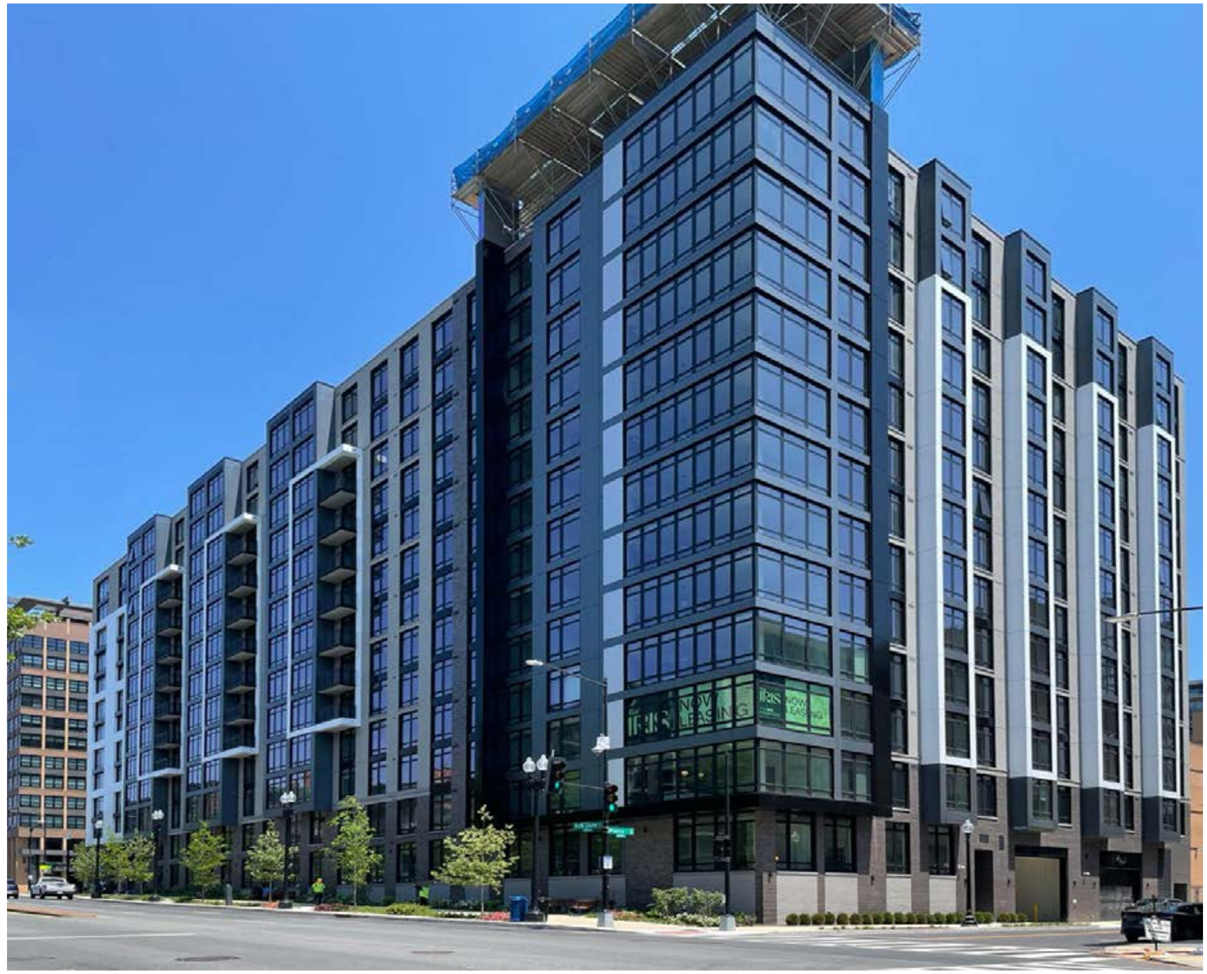

Construction continues Tuesday on the new high school/middle school in Torrington. Jim Shannon Republican-American

Torrington CT Middle and High Schools

Providing Low-Carbon Concrete Solutions Nationally

1133 North. Capital St. NE, Washington, D.C.

The IRIS



Harvard Treehouse Conference Center is under construction using 35% GGP and 35% slag to replace a total of 70% of the cement.

the Yale Wright Lab (Phase 1) is currently under construction and is also using GGP. Yale Physical Science & Engineering Building (Phase 2) has not started yet, but will use GGP.