



Sublime Systems

Performance and Field-Testing Overview for NESMEA: Sublime Electrochemical Cement

Oct 15, 2024



Our mission:

A **swift and massive impact** on global CO₂ emissions by decarbonizing cement, the key ingredient in concrete





**Cement produces
8% of global CO₂**

4 billion tons
cement /year

1ton = ~1ton

Portland
cement

of CO₂



Sublime's breakthrough

No fossil fuels or kilns

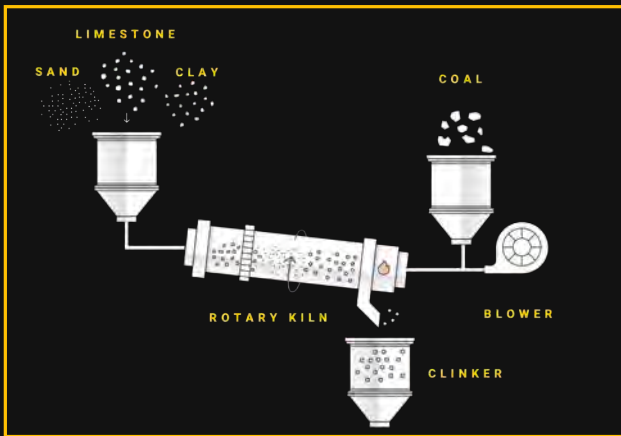
Avoids carbon capture

Drop-in replacement

Cost parity at scale

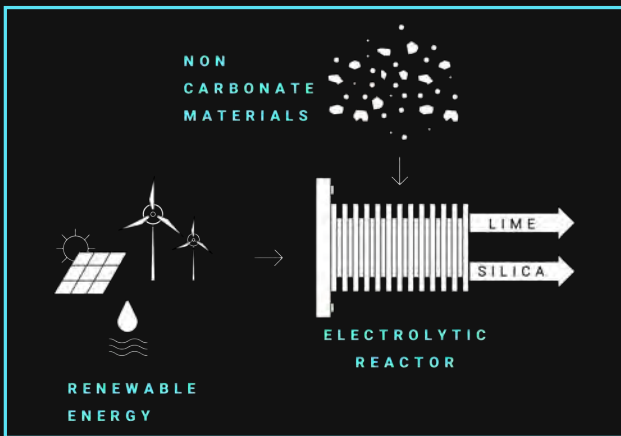
Scalable globally

Sublime Systems eliminates fossil and limestone CO2 emissions while making the same hardened concrete

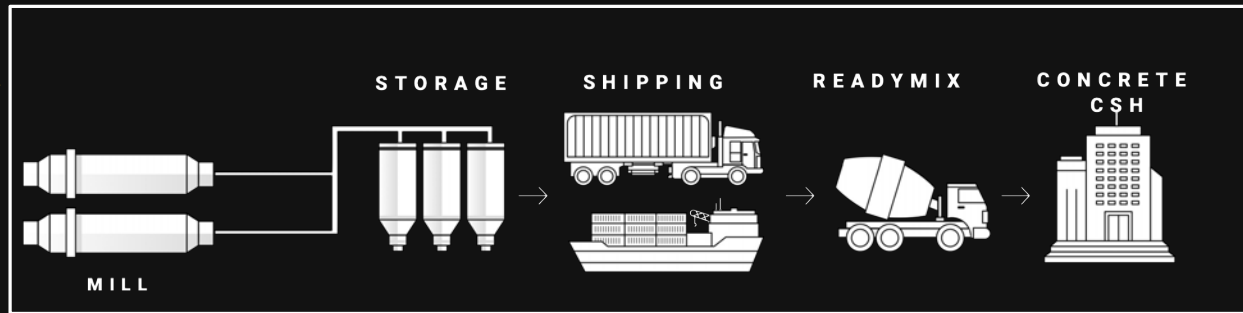


OPC Process

Coal + limestone = CO₂
 1 tonne OPC = ~1 tonne CO₂



Downstream process



Drop-in replacement

Sublime Systems

Electricity + non-carbonate rocks = CO₂ avoided

Sublime Process Overview

Sublime's process dissolves rocks into constituent minerals, so that we can assemble the ideal cement composition from pure components.

Feedstocks

Ca-Mg-Al-Fe- silicate rocks and industrial wastes (eg. Slag)



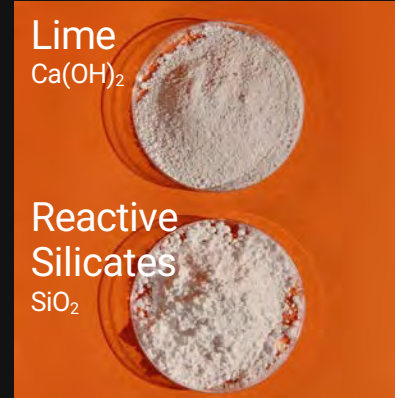
Sublime's Process



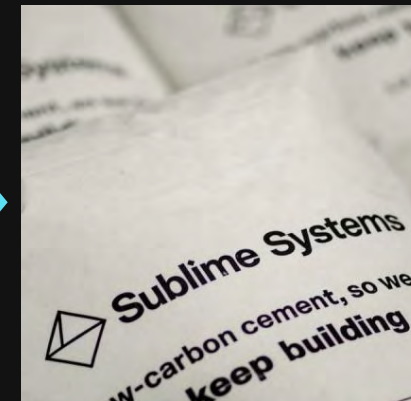
Intermediate Products

Lime
 $\text{Ca}(\text{OH})_2$

Reactive
Silicates
 SiO_2



Sublime Cement & SCMs



High-value co-products

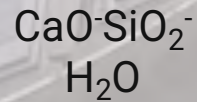
Iron oxide pigments
 $\text{Mg}(\text{OH})_2$

Sublime Cement is based on the recipe for Roman Cement

Lime CaO
Silica SiO₂
Water H₂O

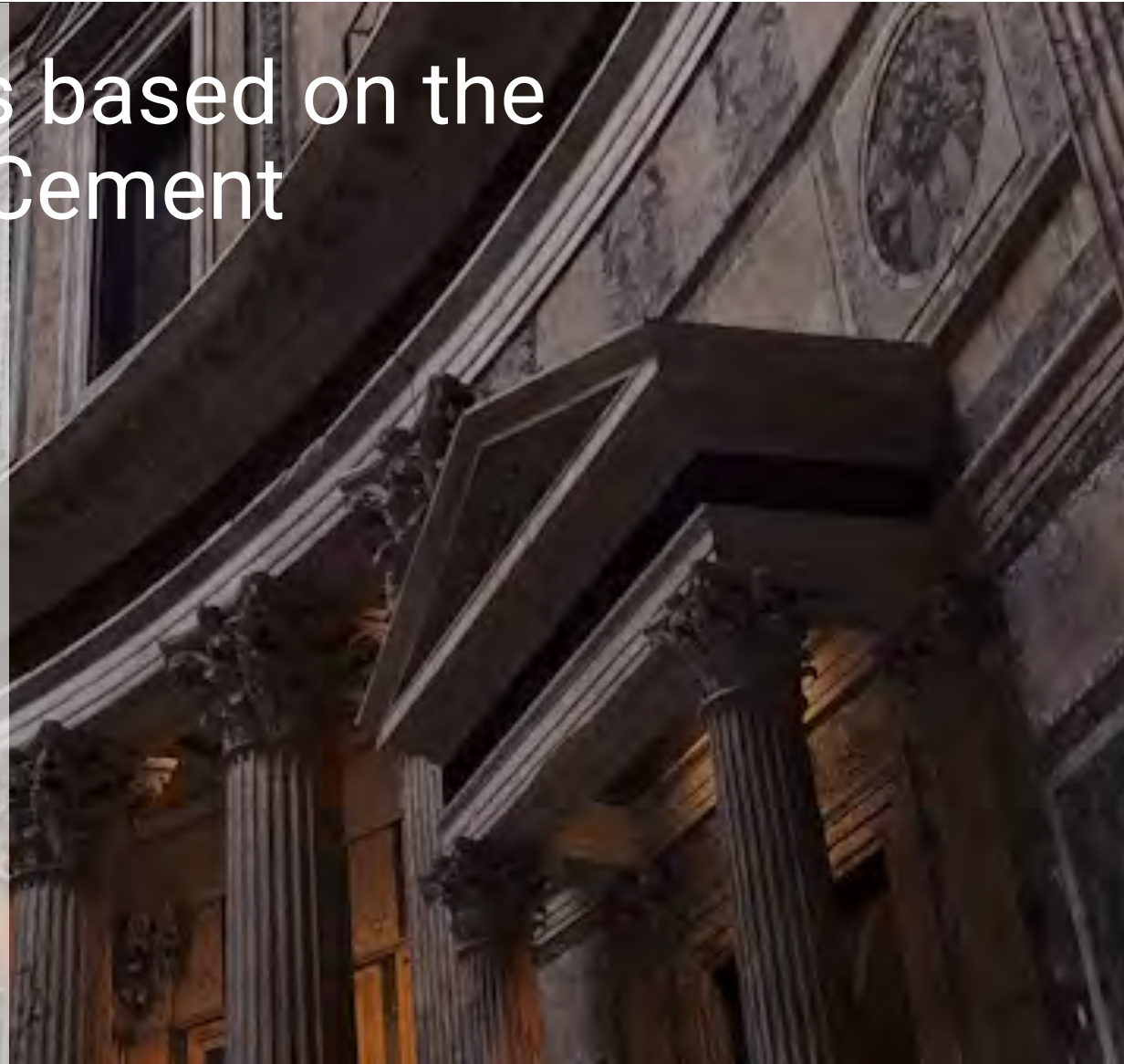


**Calcium
Silicate
Hydrate**

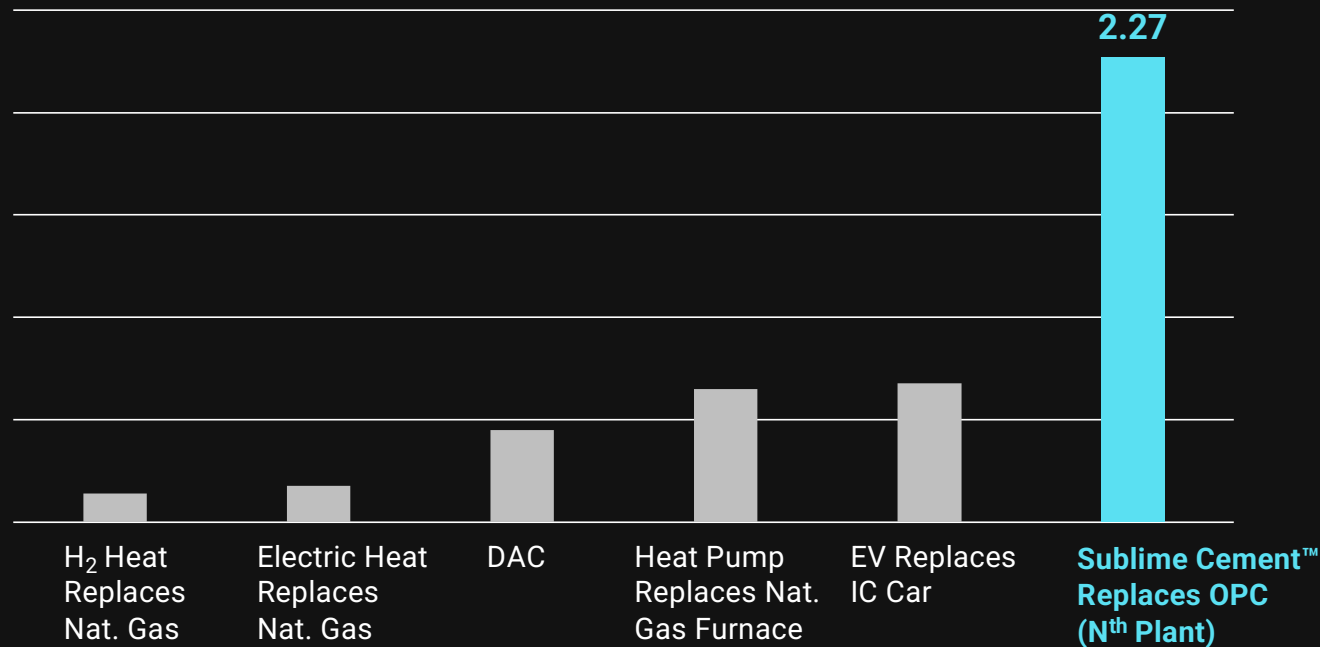


Same hardened phase as OPC

Better ultimate strength and durability

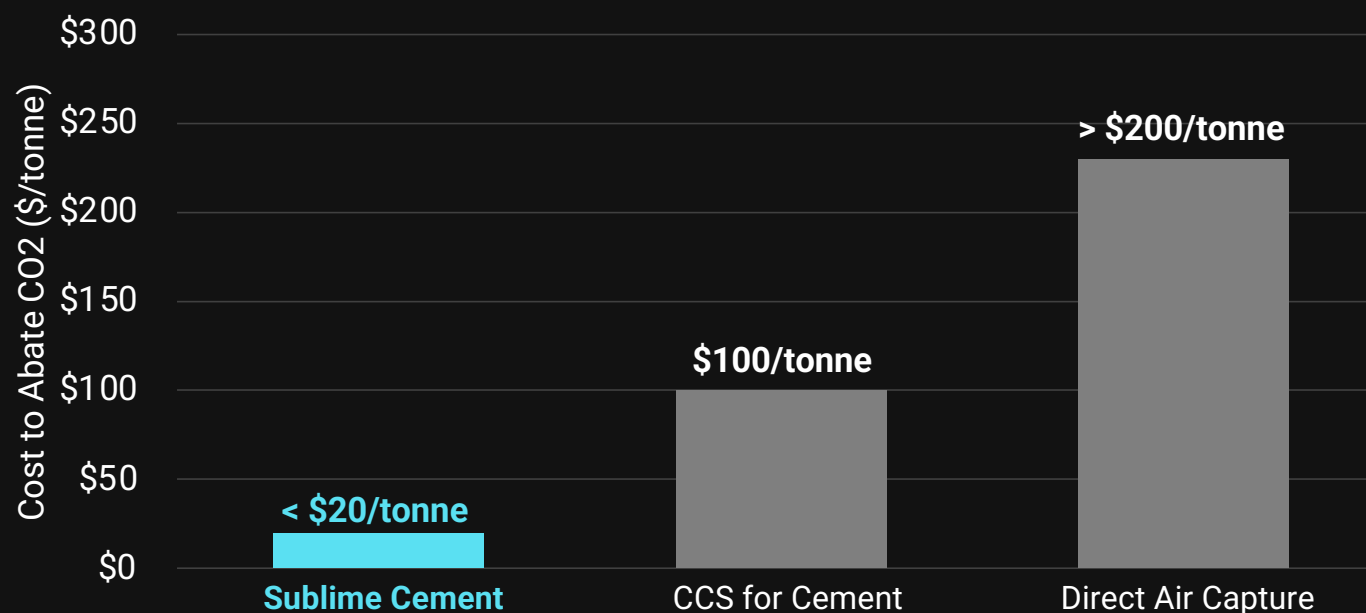


Sublime's process is the highest impact use of a green electron, in terms of CO₂ avoided/kWh.



Each kWh displaces limestone emissions (the majority emissions from traditional cement-making) *and* the energy emissions from coal.

Sublime has a distinct cost advantage, thanks to low embodied energy and “true zero” process, which **avoids the cost and complexity of CCS.**




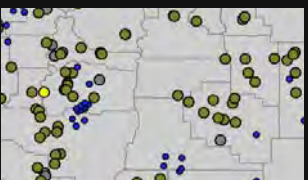


CCS is needed to prevent CO₂ from today's cement plants.

Carbon *avoidance* technologies, like Sublime's, will be the dominant in a post-carbon world.

We've worked *hard and fast* to set up for scale

We are here

	2020	2023	2026	2028
Capacity	R&D Lab 1g <i>Proof of concept</i> 	Pilot 250t/y <i>Precursor to FOAK</i> 	1st Commercial 30kt/y <i>Holyoke, MA</i> 	MegaPlant 1Mt/y <i>Full-scale</i> 
Technology Readiness Level (TRL)	TRL 4	TRL 6 <ul style="list-style-type: none"> ✓ 1000+ hours of operations ✓ ASTM C1157 achieved ✓ Preliminary EPD 	TRL 7 <ul style="list-style-type: none"> ✓ Lease activated ✓ DD complete ✓ State & local incentives obtained 	TRL 8-9 <ul style="list-style-type: none"> ✓ Siting underway ✓ Early diligence complete on top pick
Objective	Proof of Concept	Product / Process Validation	Build Full-Scale Production Customer Pipeline	Full Scale Deployment

R&D Lab – 3rd Party-Verified Best-in-Class Capability

State-of-the-art Calorimetry Lab

5 Isothermal Calorimeters → Cement



Mortar Lab



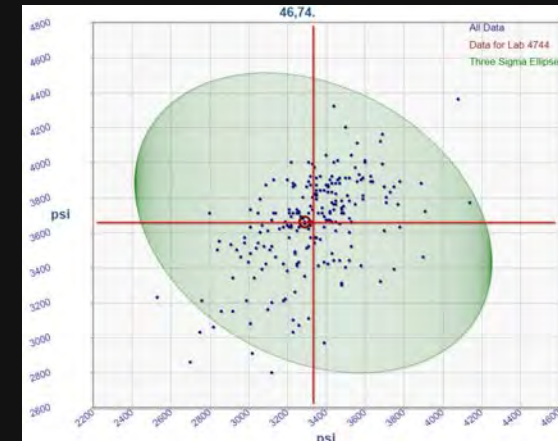
2 Semi-adiabatic Calorimeters → Concrete



Concrete Lab



- Participated in Cement and Concrete Reference Lab (CCRL) Cement Proficiency Program vs 100 other testing labs
- Scored 5/5 on:
 - Compressive Strength
 - Mortar Air Content
 - Setting Time



Scatter plot of participating lab results for compressive strength testing



Product Validation Methodology

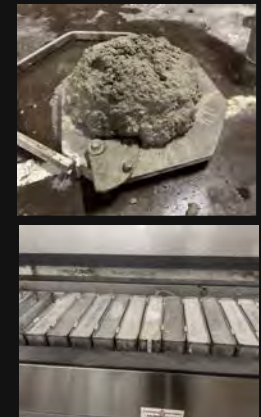
Calorimetry and Standard mortar test



Micro-concrete



Concrete



Fresh Properties:

- Set Time
- Air content

Hardened Properties:

- 1 - 28-day strengths
- Heat of hydration

Fresh Properties:

- Set Time
- Admixture compatibility

Hardened Properties:

- 1 – 28-day strengths

Fresh Properties:

- Slump / Slump retention
- Set Time
- Temperature
- Air Content
- Admixture compatibility

Hardened Properties:

- 1 – 56-day strengths
- Freeze-thaw
- Resistivity
- Scaling
- ASR



Sublime Cement Performance: ASTM-C1157-compliant

Color legend Meets target Exceeds target by >30% Exceeds target by >70%

Key Requirements	ASTM-C150	ASTM-C1157	Sublime Cement
Initial Setting Time (min)	45 - 375	45 - 420	Pass
3-Day Compressive Strength (MPa/psi)	12.0 / 1740	13.0 / 1890	Pass
7-Day Compressive Strength (MPa/psi)	19.0 / 2760	20.0 / 2900	Pass
28-Day Compressive Strength (MPa/psi)	N/A	28.0 / 4060	Pass
Heat of Hydration, max (kJ/kg)	335 (Type II(MH) only)	335 (Type MH only)	Pass
Mortar Bar Expansion (Internal Sulfates), 14 days, % max	0.040 (Type V only)	0.020	Pass
Sulfate Expansion (External Sulfates), 12 mths, max, %	N/A	0.10	Pass
ASR Expansion @ 14 days, max, % (optional)	N/A	0.10%	Pass
Fineness (m2/kg)	Measure only	Measure only	597
Specific Gravity (g/cm3)	Measure only	Measure only	2.77

Key Callout:

Sublime Cement already meets ASTM-C1157 General Use (type GU), Moderate Heat of Hydration (type MH) *and* High Sulfate (type HS) requirements.

Sublime Concrete Testing

Sublime compared to OPC		Improvement Req'd	Comparable	Slightly better	Much better
Concrete Testing Results	Status	Relative Performance to OPC			
7 Day Compressive Strength (ASTM C39)	Completed	Concrete made with Sublime Cement can have slightly lower 7-day strengths in some mix designs.			
28 Day Compressive Strength (ASTM C39)	Completed	Sublime Concrete has comparable strengths to OPC at 28-days.			
56 Day Compressive Strength (ASTM C39)	Completed	Sublime Concrete outperforms OPC beyond 28-days in compressive strength.			
Slump (ASTM C143)	Completed	Sublime Concrete is compatible with tested water reducing admixture and capable of equivalent workability.			
Air (ASTM C231)	Completed	Sublime Concrete can entrain air and is compatible with existing air entrainment admixtures.			
Time of Setting (ASTM C403)	Completed	Sublime Concrete sets faster than OPC initial set ~4 hours			

Key Callout:

- Sublime Cement makes predictable, workable concrete.
- Initial version of Sublime Cement curing times are already sufficient for many applications that don't require high strength <3 days.

Equal or Better Durability to OPC

Sublime compared to OPC		Improvement Req'd	Comparable	Slightly better	Much better
Durability Test	Status	Relative Performance to OPC			
Alkali-Silica Reaction- Accelerated Mortar Bar Test (ASTM C1260)	Completed	Sublime expansion remained below 0.1%, while OPC expansion exceeded 0.3%.			
Alkali-Silica Reaction- Miniature Concrete Prism Test (MCPT) (AASHTO T380)	Completed	Sublime expansion remained below 0.02%, while OPC expansion exceeded 0.1%.			
Alkali-Silica Reaction- Concrete Prism Test (CPT) (ASTM C1293)	Completed	No expansion observed in Sublime concrete while OPC concrete expanded 0.05%.			
Rapid Chloride Permeability Test (RCPT) (ASTM C1202)	Completed	Sublime had a Very Low , while OPC has Low/Moderate chloride ion permeability.			
Electrical Surface Resistivity (AASHTO T358)	Completed	Sublime had a Very Low , while OPC has Moderate chloride ion permeability.			
Sulfate Attack (ASTM C1012)	Completed	Sublime Cement is classified as HS.			
Rebar Corrosion Rate (ASTM G102)	Completed	Sublime showed rebar corrosion rate less than 1/3 of OPC control			
Drying Shrinkage of Concrete (ASTM C157)	Completed	Sublime concrete (after limewater curing for 7 and 28 days) shows lower shrinkage than OPC.			
Freeze-thaw resistance (ASTM C666)	Completed	Both Sublime and Control passed.			
Scaling resistance of concrete (ASTM C672)	Completed	After 30 cycles, Sublime concrete had an average rating of 3, while OPC had an average rating of 2. This test is known to be overly harsh for low-carbon mixes. We are moving to EN standard test.			

Third parties validate our product's performance and climate impact

Cradle-to-gate LCA (ISO 14044) validates Sublime's pathway to >90% carbon reduction:

- Sublime Cement™
 - 178 kg CO₂/ton (at 1st full-scale commercial)
 - 72 kg CO₂/ton (at 'Nth Plant' commercial)ale
- Today's OPC : 919kg CO₂/ton

ASTM C1157 ensures Sublime Cement can be incorporated into concrete (ACI) specifications and the International Building Code (IBC)

- ASTM C1157 specifies:
 - Set time
 - Early and late-age compressive strength
 - Key durability characteristics
 - Sulfate Attack
 - Expansion
 - Heat of Hydration

Sublime Systems

SAFETY DATA SHEET

SECTION 1 - PRODUCT AND COMPANY INFORMATION

Product Name(s): Sublime Cement™ (YZU-FML)
 Product Code(s): YZU-FML
 Uses: Used in the preparation of concrete for structural components in construction app
 Company: Sublime System
 Address: 444 Somerville #
 Telephone Number: (617) 631-4328
 Website: sublime-systems.com
 Email: info@sublime-systems.com
 Emergency Telephone Number: For Hazards/Incidents: ChemTel inc (617) 263-2023
 Date Issued: July 26, 2023
 This SDS complies with the OSHA Hazard Commun. 2012 (GHS). It may not meet requirements in other jurisdictions.

SECTION 2 - HAZARDS IDENTIFICATION

Classification of the substance or mixture:
 Carcinogen (Category 1)
 Eye Irritation (Category 1)
 Skin Irritation (Category 2)
 Skin Sensitization (Category 1)
 Repeated Exposure (Category 1)
 Single Exposure (Category 3)
 Hazard pictogram(s):

Signal word: **DANGER**
 Hazard statement(s):
 May cause cancer (3)
 Causes serious eye irritation
 Causes skin irritation
 May cause an allergic reaction (by inhalation)
 May cause respiratory irritation (by inhalation)
 May cause respiratory irritation (by inhalation)
 May cause respiratory irritation (by inhalation)

Precautionary Statement(s):
 Prevention:
 Clean special use

Revision/Date: July 26, 2023

AMERICAN ENGINEERING TESTING

October 12, 2023

To: Ms. Leslie Buzzell
 5250 Dr. James Barrack
 Sublime Systems, Inc.
 444 Somerville Avenue
 Somerville, MA 02143

Subj: Interim Report on Sublime Cement V1.0 Physical Testing
 AET Project No. P-0021496

Dear Ms. Buzzell:

Attached are the referenced test results. You submitted a sample of "Sublime Cement V1.0" which arrived at AET on April 7, 2023.

At your request, the sample was tested in accordance with the referenced test methods of ASTM C1157C1157M-23, "Standard Performance Specification for Cement". We understand the material is a proprietary formulation. However, test results obtained to date indicate that the material meets the performance requirements for Type III, HS and MS cements, given in Table 1 of ASTM C1157C1157M-23. Sulfate expansion testing is still in progress.

For further information, please contact me at the number listed below.

Sincerely,
American Engineering Testing, Inc.
 An AASHTO Accredited Laboratory - Aggregates, Cement & Concrete

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 Report Reviewed by:

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Field Testing and Validation

BOSTON SAND & GRAVEL
PC Box 9187
100 N. Washington Street
Boston, MA 02114
617-227-9000 || BostonSand.com

Project: Boston Sand & Gravel Projects

Customer: Jim Correia
180 New Rutherford Ave
Boston, MA

We are pleased to submit the following recommended concrete mix for use on the above project.

Weights per Cubic Yard - PSI @ 28 Days

Mix Code:	SUBLIME TRIAL 4K NON-AIR	
Product Code:		
Mix Desc:	4000 3/4 NA MIDRANGE	
Usage:		
SUBLIME CEMENT	lbs/cy	620

(BSG Mix Submittal w/ Sublime Cement)

Boston Sand & Gravel:

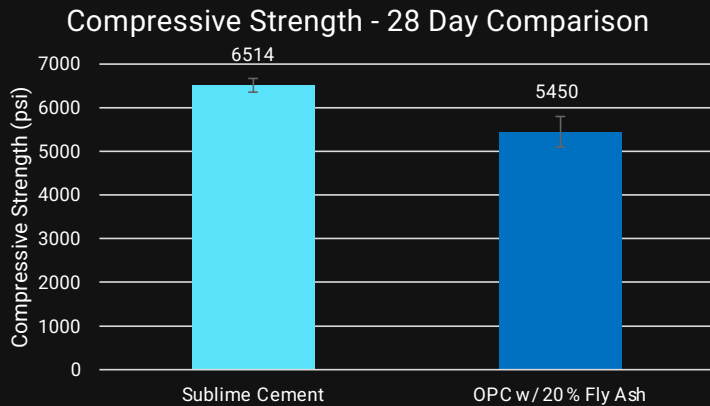
- **Industry Leadership:** Recognized as a leader in New England Ready Mix, boasting nearly a century of dedicated service
- **Diverse Project Experience:** Project portfolio includes the Central Artery/Tunnel project, wastewater treatment plants, nuclear power plants, high-rise buildings, and slurry wall construction

Testing Summary:

- Phase 1: Partner Concrete Lab Testing
- Phase 2: Test Slab Contractor Validation
- Phase 3: RM Truck Trial Batch
- Phase 4: Field Pour Validations



Phase 1: Partner Concrete Lab Testing



Data Summary:

- Sublime Cement outperforms regional benchmarks
- Sublime Cement with a design strength of 4000 psi classifies as a 5000 psi mix design at 28 days

Age, Days	Compressive Strength, psi
1	1770
2	2280
4	3100
7	4257
14	5375
28	6514
56	7850



Phase 2 & 3: Test Slab and Truck Trial Batch



Test Slab

- S&F Concrete provided Veteran finishers
- Troweled 2 mixes for finishability



Truck Trial Batch

- Mixed concrete made with Sublime Cement in RM Truck
- Performed slump retention for more than an hour
- Lost only ½ inch of slump for the duration of the test



Phase 4: Field Trial – Batch, Pump & Place



Validation Summary:

- Application: Mud slab
- Concrete batched at BSG in RM truck
 - Cold Weather Conditions: Ambient Temp 28°F ; Concrete Temp 62°F
- Delivered concrete to local Boston construction site
- 50-meter boom pumped ~ 244 ft (164 ft boom + 80 ft rubber hose)



Phase 4: Field Trial - Place and Finish



Validation Summary:

- Application: Polished topping slab
- Placement was completed using standard practices and equipment
- Two trucks were successfully loaded for the placement
 - Fresh and Hardened properties were consistent for both loads



Phase 4: Field Trial – Outdoor, complex mix design



Validation Summary:

- Application: Sidewalk section (exterior concrete)
- Placement was completed using standard practices and equipment
- One truck (6 yds) was deployed for the placement
- Mix design included air entrainer hydration stabilizer, superplasticizer, and fibers



Phase 4: Sidewalk Field Data Summary

Cement	W/C Ratios Tested	Cementitious (lb/yd ³)	Sand (lb/yd ³)	Stone ¾" (lb/yd ³)	Water (gal/yd ³)
Control	W/C =0.45	660	1323	1645	35.6
Sublime Cement	W/C =0.45	660	1205	1645	35.6

Control	Field Results Average	
	Age	Average Strengths (psi)
	7-Day	3850
28-Day	4930	
Sublime	Field Results Average	
	Age	Average Strengths (psi)
	7-Day	3850
	28-Day	4890

Finishing Sequence	Sublime Cement V1
Activity	Minutes
Batching (Initial Time)	0
Transportation/Placing	76
Screeding/Strikeoff	150
Bull Floating	167
Broom Start (Initial Set)	205
Broom Complete (Initial Set)	215
Final Set	310



What does 2025 hold?

Scale

- Complete design and break ground on Holyoke 25ktpy plant

Product

- First field trials for Sublime Cement (60-65% decarbonized)

Validation

- First field trials outside of Boston area
- Continue to increase sophistication and performance demands of field trials

Infrastructure Engagement

- Federal GSA pours
- MassDoT QCML testing
- Begin to engage with other regional DoTs



What can you do to help?

1. Update specs!

- Allow ASTM C1157 products in your specifications
- Talk to Rich Mulcahy from MassDoT!



Embrace Performance Based Standards

ASTM C1157
(Performance Based Cements)



ASTM WK70466
(Performance Based SCMs)



Multiple Performance-Based Cementitious Materials on the Horizon

What can you do to help?

1. Update specs!

- Allow ASTM C1157 products in your specifications
- Talk to Rich Mulcahy from MassDoT!

2. Be open to sharing data from new product testing broadly

3. Reach out if interested in discussing planning for Sublime approval in your state or discussing joint grant applications for federal funding greg@sublime-systems.com



Sublime is led by a diverse, energetic, and mission-driven team

216+ years of cement/concrete/construction industry experience
88+ years of project & business development experience



Leah Ellis, PhD
CEO, Co-Founder



Yet-Ming Chiang, PhD
CSO, Co-Founder



Stephen Galowitz, JD
Chief Commercial Officer



Joe Hicken

VP Policy/Business Dev.



Cayman Somerville

Director of Operations



Greg Williams

VP Product



Jesse Benck, PhD

VP R&D



Mike Corbett

VP Engineering



Raffi Mardirosian

VP Strategy



Becky Gallagher

Head of Project Development



Erin Glabets

Head of Comms



Satish Viswanathan

Head of Scale-up Engineering



Sublime is supported by world-class advisors bringing 284+ years of construction industry experience



Don Davies

Former President, MKA

34+ years of AEC industry & low carbon construction experience



Dax Kepshire, PhD

Chief Operating Officer
Americas, Fluence

18+ years of engineering, startup, and technology experience



Jeff Whidden

President, CR Minerals Company

25+ years of experience in consulting, construction, and engineering



Jeff Davis

Former VP at U.S. Concrete

49+ years of civil engineering, executive management, and concrete experience



Ted Wiley

Co-Founder, President, and COO,
Form Energy

17+ years of business development, startup, and cleantech experience



Anne Banta

Strategic Consultant, Corporate
Marketing & Communications

41+ years of experience with marketing, communications, startup, concrete, and technology experience



Sublime is backed by veteran hardtech investors



a sophisticated strategic investor



and the U.S. DOE



 **Sublime Systems**

Keep building

