Admixture Solutions for Type IL & Low-Carbon Concrete Mixtures

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Outline

1. **The Background Story**
2. Admixture Solutions for Type IL & Low-Carbon Concrete Mixtures
3. Summary / Questions

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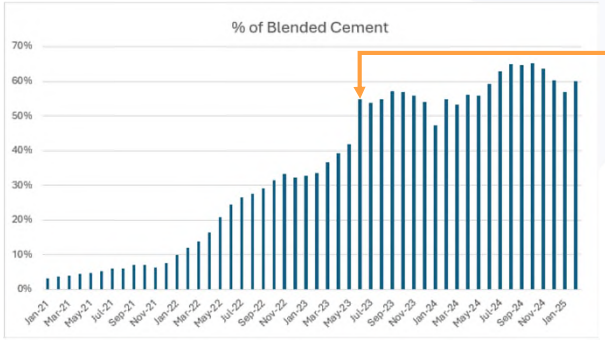
Use of Blended Cements in U.S.



U.S. market share for PLC surpassed that of traditional portland cement in June 2023.

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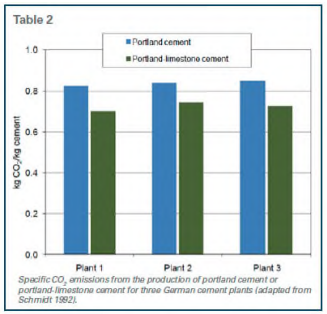
Environmental Benefit of PLC



https://www.concreteconstruction.net/how-to/concrete-production-precast/the-advantages-of-portland-limestone-cement_o

Up to 10% reduction in GWP

ACA Industry Average EPD	
Type of Cement	GWP (kg CO_2 eq / ton)
Type I/II	925
Type IL	855

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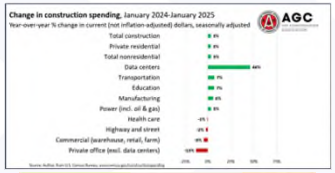
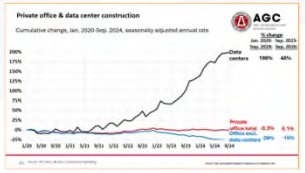
Push for Low(er)-Embodied Carbon Concrete

https://stock.adobe.com/





Hyperscalers & Others are Reducing Their Carbon Footprint!

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Example of GWP Reduction Targets

Baseline 20XX

Through 2025
20 – 30% reduction

2025 - 2030
30 – 60% reduction

2030 - 2050
Net Zero!

Concrete mixtures with low & progressively lower embodied carbon required!

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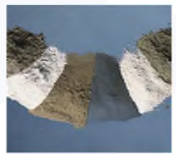
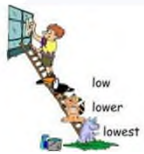
Current Driving Forces for Low(er)-Embodied Carbon Concrete

1. **Specification requires concrete with low GWP.**
2. **Specification limits portland cement content.**

➢ Type IL & other Low-carbon cements, SCMs & alternatives





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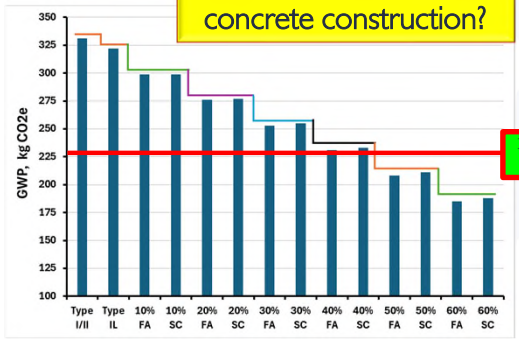
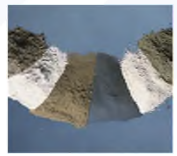
GWP Modeling… (SCM Replacement Only)

What are the impacts on concrete construction?





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Potential Impacts of Non-Optimized Low-GWP Concrete Mixtures

1. Increased water demand
2. Mix stickiness
3. Finishability challenges
4. Undesired retardation of set

WARNING: There's a limit on w/cm!

- **Strength not achieved at desired time.**
  - **Production & project schedules affected!**

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PLCs have been a "Hot Topic" in the Concrete Industry!

Guidance for Concrete Contractors … #14 in a Series

✔ Posted on February 15, 2023 in: Technical

Jim Klinger, The Voice Newsletter February 2023

Full Disclosure: Over the past year, the ASCC Technical Division fielded several Hotline calls from members experiencing difficulties related to ASTM C 595 portland-limestone cement Type1L, hereinafter referred to as "PLC" (as opposed to "OPC", ordinary portland cements, brand X,ASTM C 150 Types I and I/II and so on).

Question: What are the typical problems with PLC being reported from the field by ASCC concrete contractors today?

Answer: According to our recent survey, suspected side effects of added limestone include increased water demand, slow set time (need for adding accelerator admixtures), low strength, crusting of top surface, more shrinkage cracks, more labor required to finish. Anecdotal reports of problems with sawcutting and adhesives not sticking are being vetted by the ASCC Technical Division. Longer-term issues with durability (e.g. wear resistance, polishing issues) are being investigated as well. To date, no issues with shotcrete applications were reported.

https://ascconline.org/Home/News/articleType/ArticleView/articleId/325/Guidance-for-Concrete-Contractors-I-4-in-a-Series

Slower setting, low strength, cracking & other issues were reported in 2023.

PLCs are not all the same!

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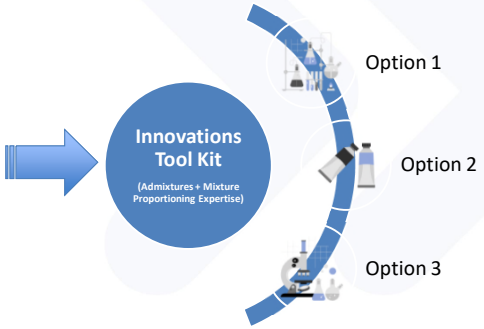
So, What's Should Concrete Producers Do?

Perform Trials to Evaluate PLCs / LECCs & Identify Potential Issues!



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Outline

1. The Background Story
2. **Admixture Solutions for Lower Embodied Carbon Concrete (LECC)**
3. Summary / Questions

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Addressing Strength-Related Issues

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Admixture Solutions for Lower Embodied Carbon Concrete

- C-S-H **Nanoparticle** Strength-Enhancing Admixtures (**seeding technology**)
- Rheology Modifying Water-Reducing Admixture

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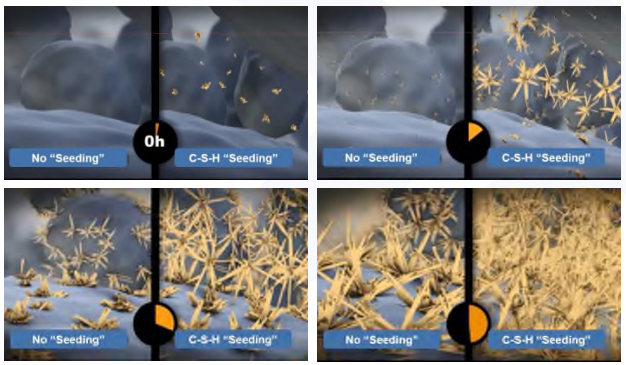
C-S-H Strength-Enhancing Admixture (SEA)



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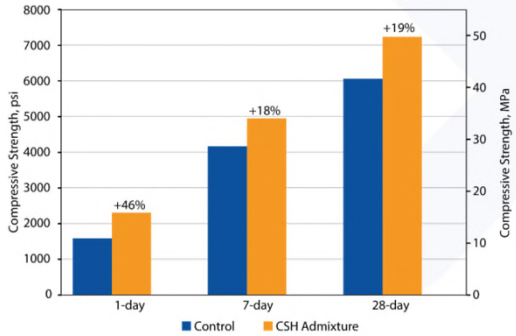
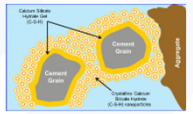
C-S-H Strength-Enhancing Admixture (SEA)



(Nominal cementitious materials content of 611 lb/yd³ [362 kg/m³] with 20 percent fly ash, w/cm of 0.47; CSH-based Strength-Enhancing Admixture dosage of 10 fl oz/cwt [650 mL/100 kg])



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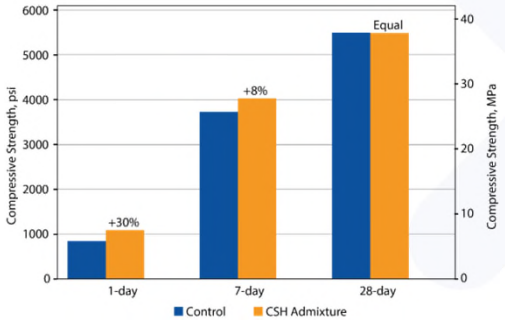
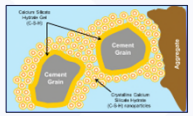
C-S-H Strength-Enhancing Admixture (SEA)





Benefits:

- Jumpstarts hydration process.
- Enhances early- & late-age strength development.
- Permits reduction in portland cement content and/or use of increased replacement levels of SCMs.
  - direct reduction in embodied carbon of concrete

Control: Total binder content - 705 lb/yd³ [418 kg/m³] with 25% fly ash, 21% limestone powder, 0.39 w/cm;
C-S-H Admixture: Dosage of 7.3 fl oz/cwt [475 mL/100 kg], Total binder content - 629 lb/yd³ [373 kg/m³] with 25% fly ash, 21% limestone powder, w/cm of 0.40

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C-S-H Strength-Enhancing Admixture (SEA): Typical Applications

- Precast Concrete
  - Meet stripping strengths
  - Reduce cycle times
  - Optimize concrete mixture to reduce carbon footprint (GWP)
  - Enhance product aesthetics
- Cast-in-Place Concrete
  - Expedite construction
  - Optimize concrete mixture to reduce carbon footprint (GWP)

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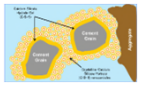
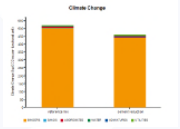
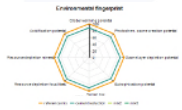
SEA Application: Pier 27 Residential Building - Toronto, Canada



- 35-storey residential building completed Summer 2019;
- ~ 32,700 yd³ (25,000 m³) of concrete;
- 3,900 yd³ (3,000 m³) of concrete optimized to achieve high-early strength in 16 – 18 h;
  - lower cementitious materials content
  - workable and pumpable; slump loss minimized
- Received the "Material Development & Innovation Award" from Ontario Concrete Awards in Dec. 2019.



Overall reduction in environmental footprint



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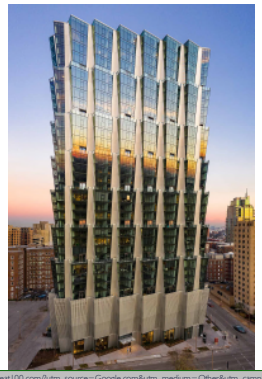
SEA Application: 100 Above the Park, St. Louis



Owner: **MAC Properties**

Location: **St. Louis, MO**

Architect: **Studio Gang Architects**

Engineering Firm: **Magnusson Klemenic Associates**

General Contractor: **Clayco**

Concrete Contractor: **Concrete Strategies, LLC**

Concrete Supplier: **Kienstra Co.**

PT Concrete Mixture: **3K (21 MPa) @ 24 hours; 7.5K (52 MPa) @ 28 days**

https://live at100.com/?utm_source=Google.com&utm_medium=Other&utm_campaign=Google MyBusiness&utm_content=Website&utm_term=Button&rdnaLabel=GoogleMyBusiness

https://www.concrete.org/aboutaci/honorsandawards/awards/projectawards/pastwinners/2022.aspx

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SEA Application: Portland Cement Content Limited by Spec.

- **Max. portland cement content:** 450 lb/yd³ (267 kg/m³)… **Type I**
- SCMs available to producer include fly ash & slag cement
- Stripping strength: **3,500 psi (24 MPa)**

- **Producer opted to use slag cement**.
  - 40% of total cementitious materials content
- **Strength-enhancing admixture** was used @ 20 fl oz/cwt (1.3 L/m³).
  - Strength at stripping: 4,740 psi (32.7 MPa)

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SEA Application: Type III Cement Replaced with Type IL Cement

- Mix also has fly ash
- Stripping strength: 3,500 psi (24 MPa)
  - **ISSUE: Overnight strength reduced** when switch was made to PLC

- **Strength-enhancing admixture**

+

Accelerating admixture.

- 1-d Strength: 4,890 psi (33.7 MPa)

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Addressing Mix Stickiness & Finishability Issues

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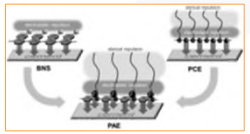
Rheology Modifying Water-Reducing Admixtures

…for production of high-performance concretes with low viscosity.



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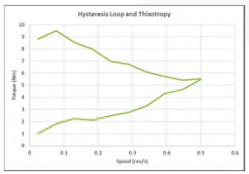
Rheology Modifying Water Reducers for Low-Viscosity Concretes

Rheological parameters determine how materials flow and move…

Measured Parameters
- Static yield stress
- Dynamic yield stress
- Plastic viscosity
- Thixotropy



Concrete Properties Impacted
- Workability
- Stickiness/feel
- Filling capacity
- Passing ability
- Mixture stability
- Pumping
- Placing
- Handling
- Finishing

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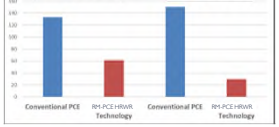
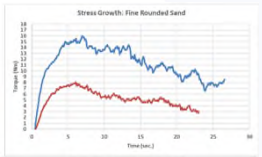
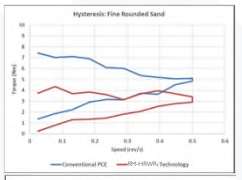
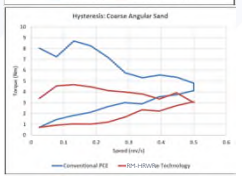
Performance Comparison…

Mixture Parameters
600 lb/yd³ (356 kg/m³) high-alkali cement
0.42 w/c
Target slump: 6 – 7 in. (150 – 175 mm)









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Rheology Modifying HRWRs for Low-Viscosity Concretes

- **Identical mix design**
- **Identical slump flow**

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Response to Pumping

Pump Pressure Reduced by ~20%

2,400 psi

Standard Type I L Concrete Mixture

2,000 psi

with RM Type A Admixture

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Response to Vibration Energy

Identical slump concrete mixtures

Reference Concrete

RMA-Treated Concrete

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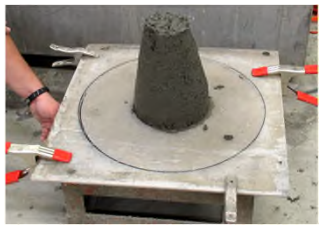
Response to Vibration Energy

Identical 4-in. (100-mm) slump FRC concrete mixtures vibrated for 10 s.



Lignin-based MRWR

RM Type A Admixture

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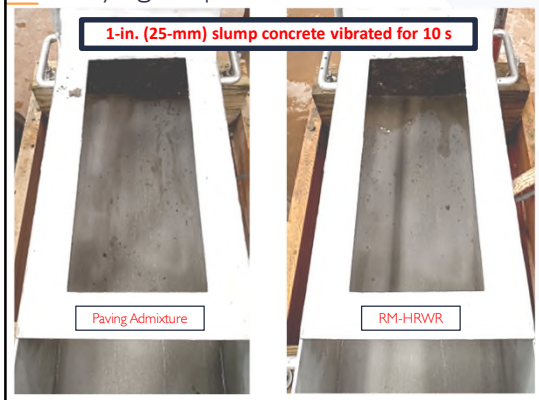
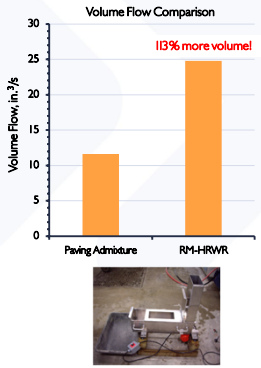
Quantifying Response of RM Admixture to Vibration

1-in. (25-mm) slump concrete vibrated for 10 s





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RM Admixture Benefits

Reference PLC Mix

Solution for Harsh and Sticky Concrete Mixtures

- Extruded much easier
- Improved Flow
- Reduced Energy Use
- Smoother finish with noticeably fewer voids and imperfections

RM Admixture Mix

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Facilitating Placement of FRC @ Amazon Distribution Center, CA






Twisted Rope Synthetic Macrofiber
+
Rheology Modifying Admixture

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Application of RM Admixture in Precast Concrete


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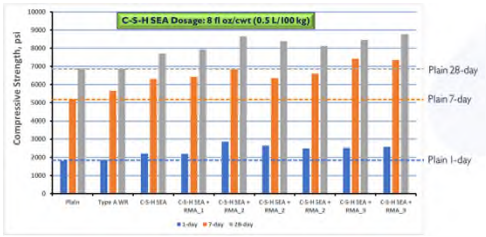
Synergistic Performance

C-S-H Strength-Enhancing Admixture
+
Rheology Modifying Admixture

→ Performance Benefits in Concrete



Improved placement (and strength)

- Improved surface finishing
- Faster placement in paving machine
- Higher early strengths without accelerating time of set
- Earlier opening to traffic
- Ability to utilized lower quality aggregates
- Possible improved air-void with MasterEase
- Lower w/cm → improved durability
- Cost savings with cement reduction
- Lower CO_2 footprint with cement reduction

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Addressing Time of Set & Air Entrainment Issues

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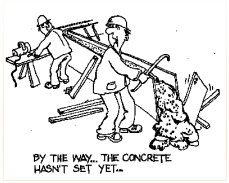

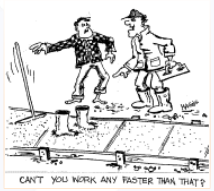

Concrete Time of Setting

Always a compromise!

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Accelerating Admixtures

PURPOSE: Added to concrete to shorten time of set and accelerate early-age strength development.

Types / Classes:

1. Calcium Chloride
2. Admixtures containing Calcium Chloride
3. Nonchloride, noncorrosive
4. Nonchloride, noncorrosive, sub-freezing

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Effect of Concreting Materials on Air-Entrainer Dosage

	Air-Entraining Admixture Dosage
Cement Alkali ⇧	⇧
Cement Fineness ⇧	⇧
Cementitious Materials Factor ⇧	⇧
Fly Ash LOI ⇧	⇧
Pigments – carbon black / black iron oxide ⇧	⇧
Integral-coloring agents (loading rate dependent)	⇕
Aggregate Topsize ⇧	⇩
Gradation (% retained on 30 & 50 Mesh) ⇧	⇩
Sand / Aggregate (s/a) ⇧	⇩

Trial mixes should be performed to re-establish AEA dosages due to material changes.

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In Summary…

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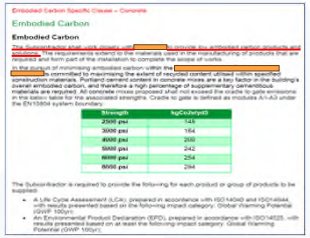
Summary

- Type IL & blended cements are here to stay!
  - Lower GWP benefit
- Admixture solutions for Type IL & low(er)-embodied carbon concrete are currently commercially available.
  - C-S-H Nanoparticle-Based Strength-Enhancing Admixture
  - Rheology Modifying Admixture
  - Accelerating Admixture

Be Informed


Embodied Carbon Specific Clause – Concrete

Embodied Carbon

Embodied Carbon

Strength	kgCO2e/cm3
2500 psi	148
3000 psi	164
4000 psi	200
5000 psi	242
6000 psi	254
8000 psi	284

- Workability
- Slump Retention
- Initial Finishing
- Final Finishing
- Form Stripping
- Post Tensioning
- Strength Development

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For a Successful Low-Embodied Carbon Concrete Project…

Collaboration is required among all parties!

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Thank You!

Questions

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Email: charles.nmai@masterbuilders.com

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