Changes to ASTM Cement and Concrete Standards to Facilitate Sustainable Initiatives

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An ACI Center of Excellence for Carbon Neutral Concrete

The Path Forward for Concrete and how ASTM standards allow that

Less clinker in cement, less cement in concrete, less concrete in construction

- Replace clinker content in cement
  - Use blended cement (ASTM C595/C1157) or replace clinker with supplementary cementitious materials (SCMs) at concrete plant
- Use less cementitious materials
  - Optimized aggregate grading (allowed in C94)
  - Lower cementitious content
- Optimize designs & new mixtures

Use alternative SCMs and/or alternative cementitious materials

Spec. development is taking place… But more to do

First… what is a specification?

- Part of a contract – a legal document
- For materials
  - Basis for a purchase agreement (i.e., contract) between a buyer and a seller
- For construction
  - Part of a construction contract which consists of
    - Contract documents (i.e., specifications)
    - Drawings
- Specifications are not textbooks or research reports
- Cannot limit a property unless it can be measured

Comparison – Concrete-Making Materials

Prescriptive Specification

- *Generally* - Places the material into a defined category, based on chemical or physical properties
- Implies specific properties to the purchaser (*example: ASTM C618 Class F ash is low calcium, mitigates ASR*)
- Sets specification limits that are rigid and can misrepresent a material.
- Implies all materials in the same category perform the same

Performance Specification

- Measures, reports, and in some cases limits properties but relates the material properties to performance outcomes
- If materials are categorized, it is based on expected performance (example ASTM C1157 Type HS high sulfate resistance, MS moderate sulfate resistance)
- Lack of chemical & compositional limits allows multiple materials to be specified for the same performance

Moving to Performance Specifications

- Standard specifications in U.S. and Canada are consensus-based and developed by volunteers
- For nearly 120 years, since standard specifications have existed, prescription has been the common approach
- Gaining consensus for performance-based specifications is difficult – what is performance?
- Engineers and contractors have more responsibility under performance-based specifications

- ✓ *Formed in 1902*
- ✓ *First cement standard 1904*
- ✓ *Issued C150 for portland cement in 1940 using same five type designations used today*

To meet the 2030 goals for Reduction in GWP, start with the Low-hanging Fruit:

Use currently available levers to reduce CO_2 emissions

Adopt Materials, Mixtures, and Methods which meet current standards and codes without compromising performance or durability:

1. **Use Portland-Limestone Cements (up to 15% interground limestone)**: →**10% CO_2** reduction over Portland cement while meeting the same performance targets.
2. **Increase levels of SCMs**: ---**CO_2 reduction is proportional to % replacement of cement (25-75%)**---- results in better durability in resisting chloride ingress, sulfate attack, ASR, and thermal cracking, but can impact set and early-strengths.
3. **Optimize total aggregate gradations and use of admixtures**: --- can **reduce cement paste fraction (and CO_2) by 5-15%,** while reducing both concrete shrinkage and permeability.

In North America, all of these levers are allowed by the ACI 318 building code, and by ASTM & CSA specifications, and all can be done simultaneously to obtain a cumulative reduction in GWP.

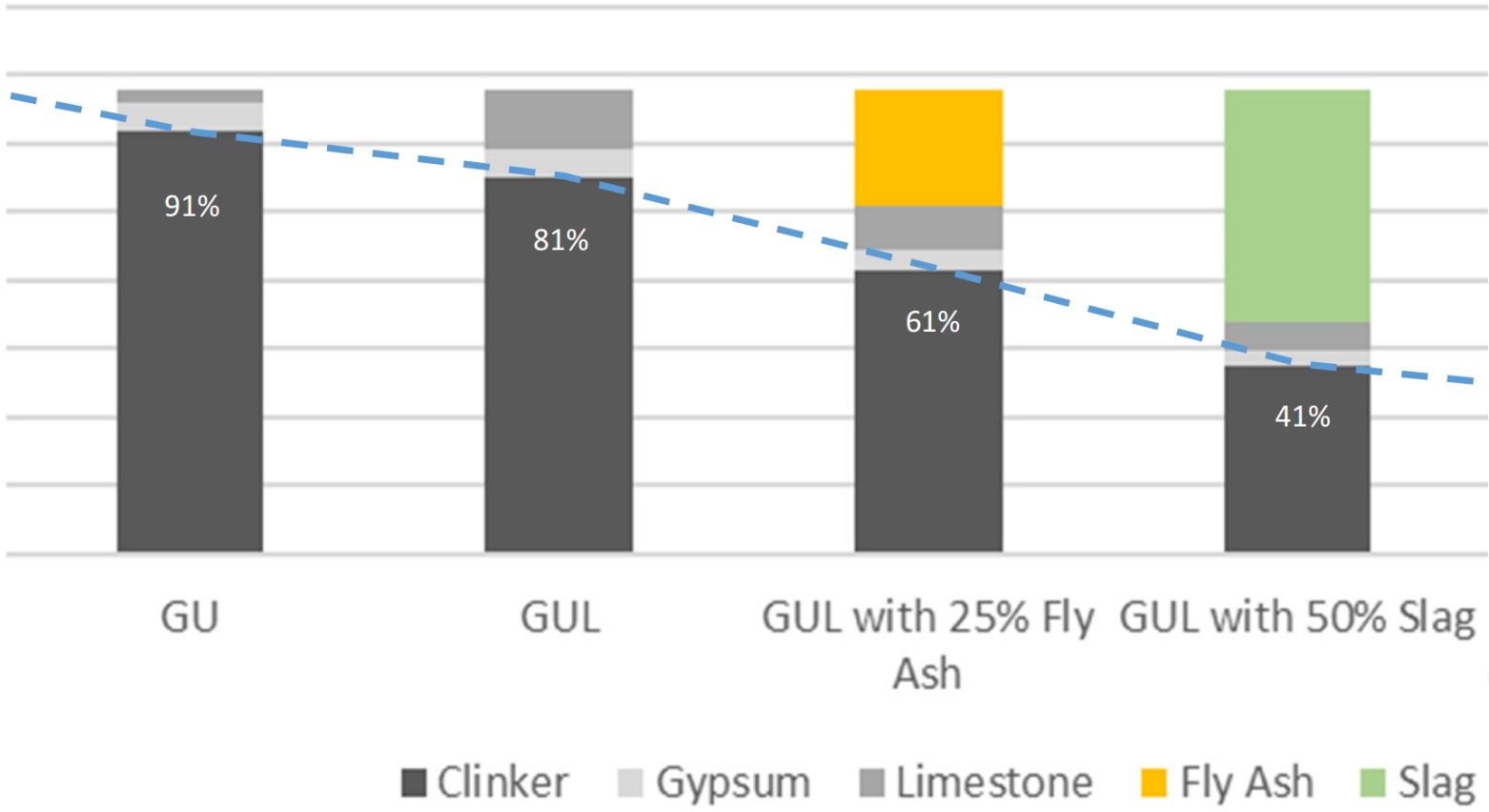
Current Specs allow these materials and mixtures

- **ASTM C595-*Blended Cements* allows:**
  - Portland-limestone cements (Type IL) with up to 15% interground limestone that can be used together with SCMs. (Type IT)
  - Blended cements and separately added Supplementary Cementitious Materials (SCMs), including ground glass, natural pozzolans, harvested fly ash and ternaryblends.
  - ASTM C94 allows Optimized Total Aggregate Gradations

Industry Status:

- Portland-limestone cement is now over 50% of the most widely used cement type across USA and the majority of that produced in Canada
- Almost all concrete contains SCMs—although replacement levels are sometimes limited by prescriptive agency specs (and less SCM is typically used in winter construction)
- The paving industry makes used of optimized aggregate gradations, but there are supply chain issues and some government agency specs can make it difficult.

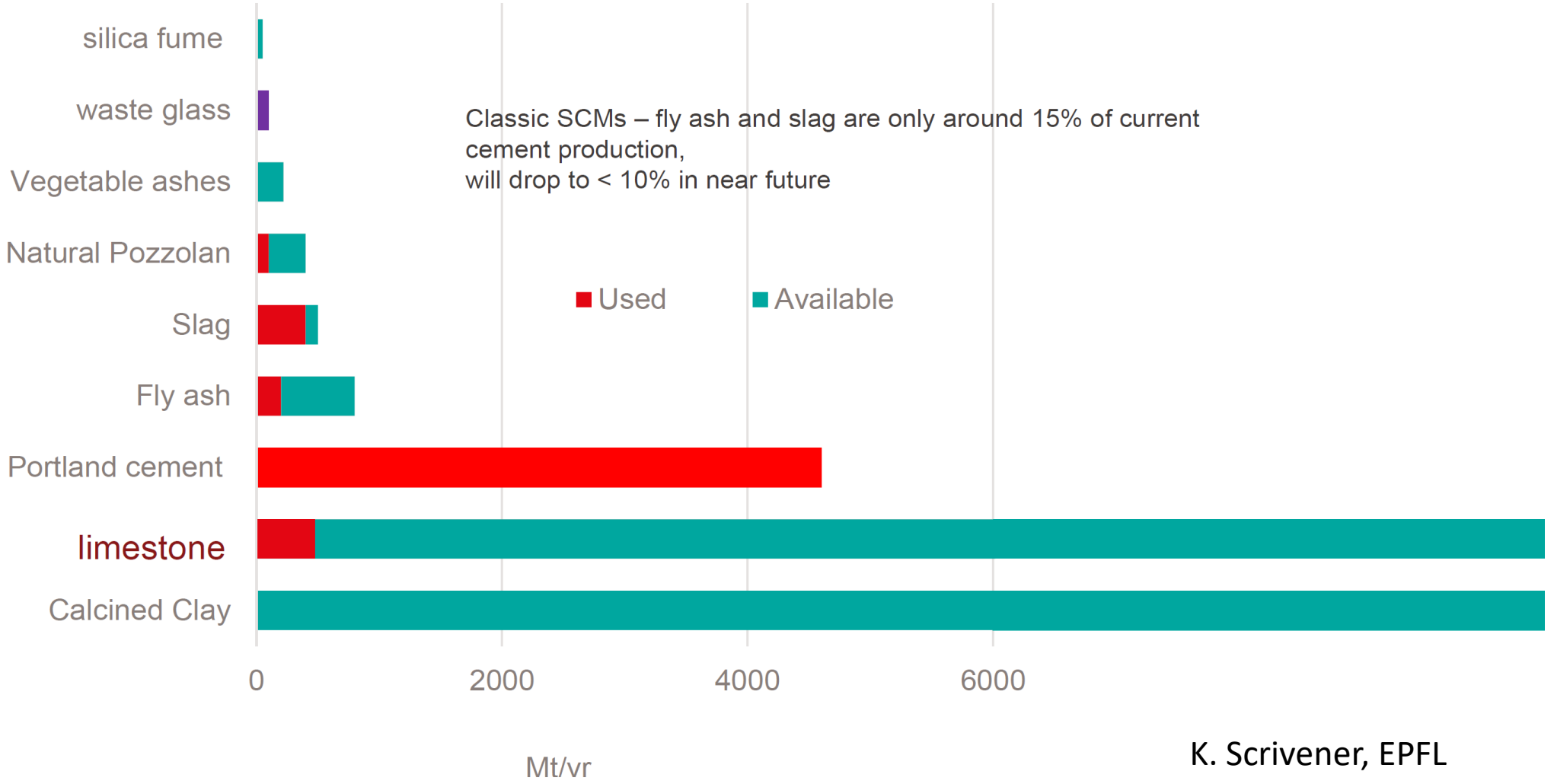
% Clinker in binders with PLC and SCMs



Cement Association of Canada 2021

But the availability of Current SCMs is changing

Availability of SCMs



K. Scrivener, EPFL

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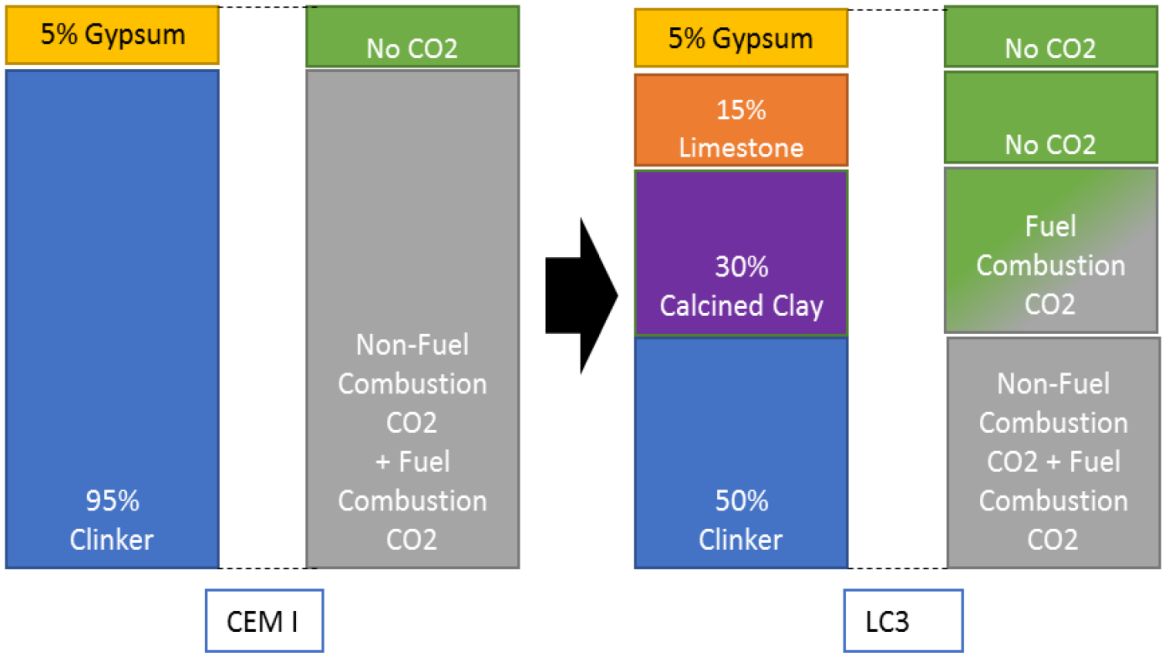
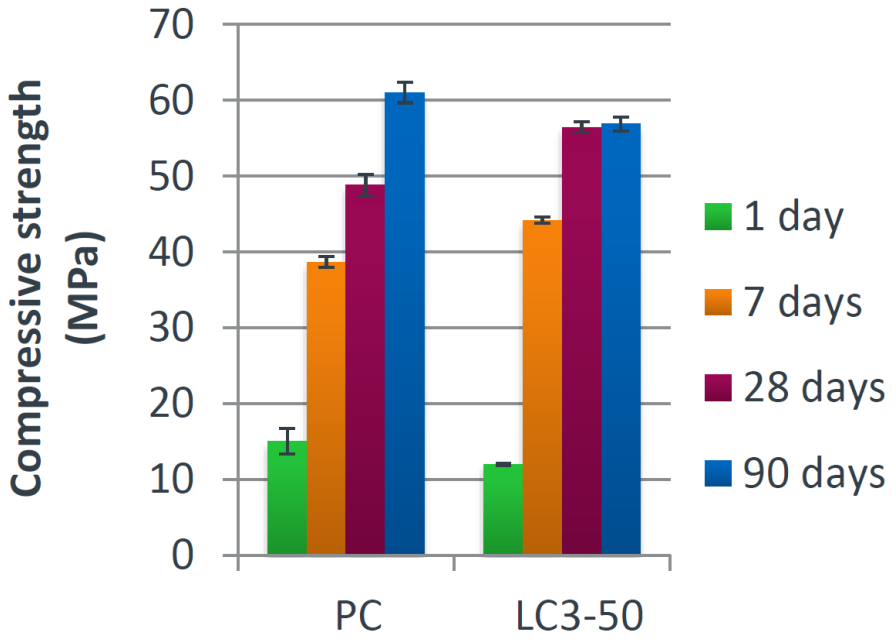
What is LC^3



LC^3 is a family of cements, the figure refers to the **clinker** content



- 50% less clinker
- 40% less CO_2
- Similar strength
- Better chloride resistance
- Resistant to alkali silica reaction

The clay in LC3 can have as little as 40% kaolin content---high purity metakaolin is not needed

Example: Are there standards barriers to LC^3 Cements?

- **LC3: Limestone-Calcined Clay Blended Cements**
- Have shown excellent properties and durability while **replacing 50% Portland cement clinker.**
- Why calcined clay? Globally, it is almost as widely available as limestone, so is not supply limited like most SCMs.
- Calcining of clays does not release CO2

- **CSA A3001/ASTM C595/AASHTO M240** allow **Type IT** cements with up to 15% limestone together with any SCM including calcined clay (a natural pozzolan). **Limestone contents higher than 15% would require a change.**
  - But most DOTs do not allow Type IT
- The **ASTM C1157** performance spec., **would allow all LC3 combinations**
  - But most US DOTs and specifiers do not allow C1157 cements

The ACI 318-19 Code allows both ASTM C595 and C1157 cements; CSA A23.3 allows blended cements

Barriers to Performance Specifications

- We need to learn how to use performance-based tests

Designation: C1157/C1157M – 20a

Standard Performance Specification for Hydraulic Cement[1]

This standard is issued under the fixed designation C1157/C1157M; 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 performance specification covers hydraulic cements for both general and special applications. There are no restrictions on the composition of the cement or its constituents (see Note 1).

NOTE 1—There are two related hydraulic cement standards, Specification C150/C150M for portland cement and Specifications C595/C595M for blended cements, both of which contain prescriptive and performance requirements

ization 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:*[2]

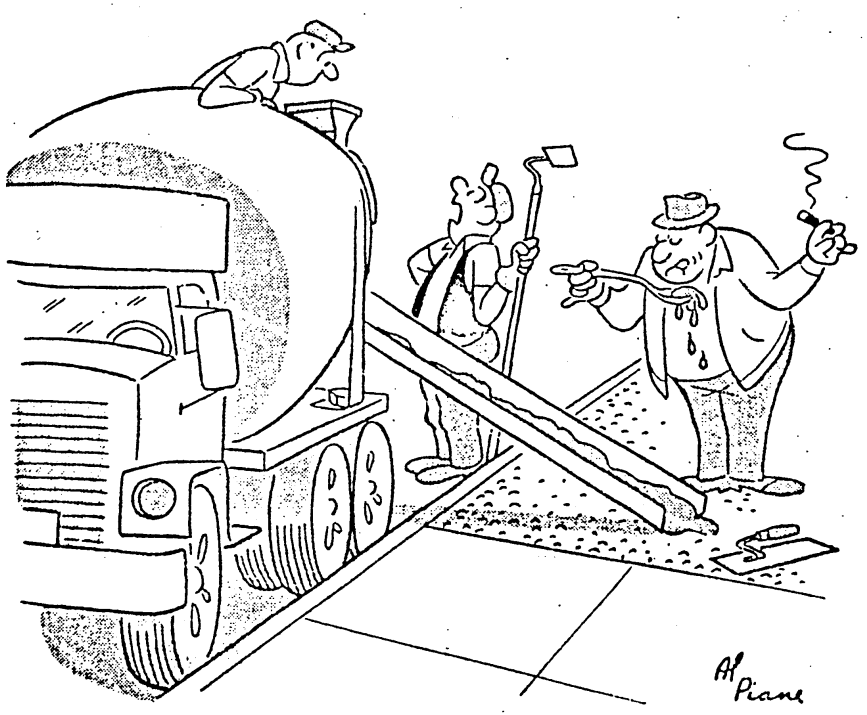
C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50 mm] Cube

1. Scope*

1.1 This performance specification covers hydraulic cements for both general and special applications. There are no restrictions on the composition of the cement or its constituents (see Note 1).

Barriers to Performance Specifications

- We need to learn how to use performance-based tests
  - ASTM C1157 – was adopted in 1992
    - Only a small number of states have adopted; it is included in ACI Code 318 but rarely invoked
    - Few producers
  - ***Users say they want performance, but for some reason still want to know what is in the cement----they want to be a chef***
  - Owners QA/QC is based on historic, legacy prescriptive approaches
  - New tests present additional challenges by measuring properties engineers and architects do not comprehend (example: calorimetry)



"He says it needs more sand!"

Moving to Performance Specifications

- Performance based specifications require performance-based tests
  - Currently rely mainly on prescriptive tests, some are nearly 100 years old
- Tests need to be practical, fast (relatively)
- Adoption is slow
  - Need correlation with field performance (takes time)
- Precision vs. Accuracy (reproducibility is most important)

Moving to Performance Specifications

- Performance-based specifications must rely more on reproducibility – demonstrating consistency is at the heart of performance-based specifications
  - The users can learn to live with not knowing what the material is if it can be demonstrated to perform consistently and if the performance can be substantiated by testing.
- Existing data on sampling and uniformity is sparse but also outdated

Recent Success – Processed coal ash harvested from landfills is now allowed

When processed, harvested ashes can perform well as 'fresh' fly ash.
This potentially allows harvesting of 1 to 2 Billion tons of ash from over 500 sites across the US

Designation: C618 – 23$^{\varepsilon 1}$

Standard Specification for
Coal Ash and Raw or Calcined Natural Pozzolan for Use in Concrete[1]

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *coal ash, n*—fly ash and bottom ash resulting from the process of combustion of ground or powdered coal obtained either from current power plant production or harvested from landfills or impoundments.

5. Materials and Manufacture

5.1 It is permitted to process coal ash and natural pozzolans to meet the requirements of this specification.

NOTE 3—Processing may include but is not limited to one or more of the following unit operations: grinding, drying, sieving, de-agglomeration, sizing, and carbon removal.

Recent Success –**R3 Reactivity Tests for SCMs**

Designation: C1897 – 20

Standard Test Methods for Measuring the Reactivity of Supplementary Cementitious Materials by Isothermal Calorimetry and Bound Water Measurements[1]

This standard is issued under the fixed designation C1897; 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 These two alternative test methods are used to assess the chemical reactivity of a supplementary cementitious material (SCM) as determined by measurements of cumulative heat release or bound water content of hydrated pastes composed of the SCM, calcium hydroxide, calcium carbonate, potassium sulfate, and potassium hydroxide cured at 40 °C for 3 and 7 days.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C114 Test Methods for Chemical Analysis of Hydraulic Cement

C125 Terminology Relating to Concrete and Concrete Aggregates

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

Provides tests that evaluate the reactivity of natural and manufactured pozzolans and to distinguish them from inert fillers

The intent is to dd limits to a new Performance Specification for SCMs

Recent Success – Ground Glass Pozzolan

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.

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

Provides a pathway for acceptance of pozzolans derived from recycled waste glass.

Will be referenced in 2024 ACI 319 Building Code

Recent Success – Foam Index Test

Under ASTM C09.48. Allows rapid testing of required AEA dosages in the lab together with cement, SCMs and other chemical admixtures

Designation: C1827 – 20

Standard Test Method for Determination of the Air-Entraining Admixture Demand of a Cementitious Mixture[1]

This standard is issued under the fixed designation C1827; 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 test method is for the determination of the air-entraining admixture (AEA) demand of a mixture of cementitious materials, AEA, and water.

3.1.1 For definitions of terms used in this test method, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *absolute volume of AEA, n*—the air-entraining admixture demand expressed as volume of un-diluted air-entraining

Recent Success – Cements that Set by Carbonation

Designation: C1905/C1905M – 23

Standard Specification for Cements that Require Carbonation Curing[1]

This standard is issued under the fixed designation C1905/C1905M; 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 cements that require controlled exposure to carbon dioxide to achieve strength, referred to as carbonation curing. These cements are for use in concrete that does not contain steel reinforcement. There are no restrictions on the constituents of the cement. The producer is required to demonstrate that carbon dioxide is chemically bound by the cement.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C114 Test Methods for Chemical Analysis of Hydraulic Cement

C183/C183M Practice for Sampling and the Amount of Testing of Hydraulic Cement

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

This specification provides a pathway for acceptance of such products, such as Solidia

Recent Success – Tests for Cements that Set by Carbonation

Designation: C1910/C1910M – 23

Standard Test Methods for Cements that Require Carbonation Curing[1]

This standard is issued under the fixed designation C1910/C1910M; 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 These test methods cover procedures for testing cements that require carbonation curing and are intended for use in concrete.

1.2 The procedures are organized in the following sections:

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)

Provides a procedure for testing strength of such cements, as used in the C1905 Specification

Recent Success – Strength Test for Alkali Activated Cements

Designation: C1928/C1928M – 23

Standard Test Method for Compressive Strength of Alkali Activated Cementitious Material Mortars (Using 2-in. [50 mm] Cube Specimens)[1]

This standard is issued under the fixed designation C1928/C1928M; 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 test method covers determination of the compressive strength of alkali activated cementitious material mortars, using 2-in. [50 mm] cube specimens.

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

Provides a test method suitable for measuring strength development of such non-Portland cements

Under Development

- ASCM Performance Spec – Builds on the Foam Index and R3 tests
- Colloidal Silica – for use in concrete as an ingredient
- ASTM C1697 – Modifying for blending SCMs to meet a specification (currently each component of a blended SCM has to meet specification)
- ASTM C595 “Type C” – Blended cement spec, add “Type C” for composites – go beyond Type IT

- Take Away – Performance Based specifications are coming but don’t expect a miracle – they take time

https://theproductiveengineer.net/hardest-or-easiest-work-first-what-the-research-shows/

Revisions Under Development

Designation: C1697 – 21

Standard Specification for Blended Supplementary Cementitious Materials[1]

1. Scope*

1.1 This specification covers blended supplementary cementitious materials that result from the blending or intergrinding of two or three ASTM compliant supplementary cementitious materials, for use in concrete or mortar where hydraulic or pozzolanic action, or both, is desired. The supplementary cementitious materials include slag cement conforming to Specification C989/C989M, natural pozzolans and coal fly ash conforming to Specification C618 and silica fume conforming to Specification C1240.

Limitations of C1697

As stated in the Scope, currently each SCM in the blend has to meet specification.

1. So even if the blended material meets C1697, it cant use for example, a fly ash that is too coarse or has a high LOI.

2. Because each raw material has to be a specified SCM, this would prevent blending of calcined clay pozzolan with ground limestone to make an LC2 for use at a concrete plant to replace 50% of Portland cement

So what else is needed?

- There are many new start-up companies developing new types of cementitious materials that have application in producing low-carbon concrete.
- They are now coming to ASTM meetings because they realise that to be adopted in construction and in building codes, their products need to either fit in the existing specifications or that new specifications will need to be developed.
- Many will likely need additional test methods, or modifications to existing test methods, to allow their product to be tested in specifications.
- **Rather than trying to create product-specific specifications, it would be more robust to develop a single performance specification.**

But Low-carbon materials must be able to be used with existing construction infrastructure

1) Able to be used by the existing materials production and logistics infrastructure,

2) related to cement and concrete use, which includes how the industry specifies and tests concrete and designs concrete structures,

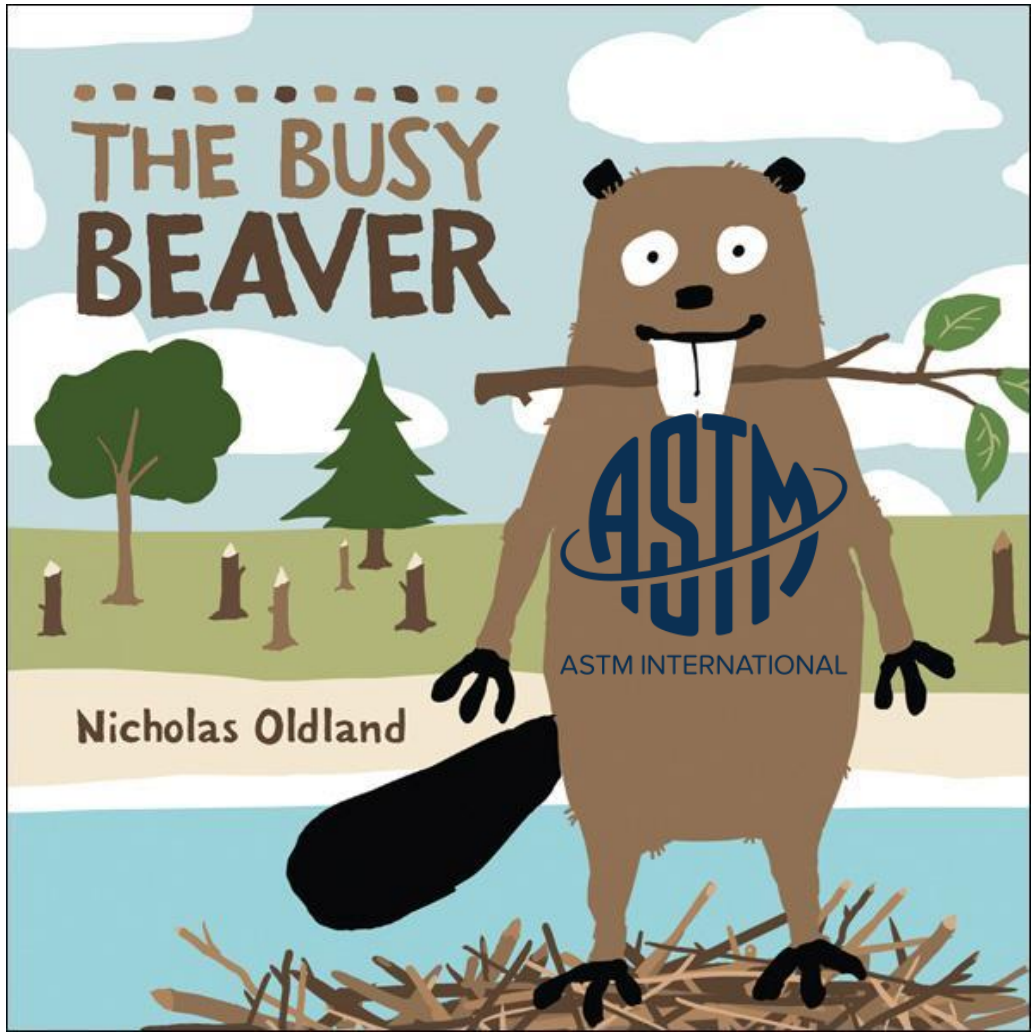
3) related to the risk of adopting new technologies in a risk adverse industry.

Given the existing infrastructure for manufacturing, delivery and installation of concrete, and the massive capital investment that would be required to change it, advancements in carbon reduction must be made within this infrastructure.

In Summary

- ASTM standards are evolving and new specifications help allow the use of more sustainable materials.
- New Specifications and revisions to existing ones are being developed, but due to the consensus process, negatives need to be addressed. ---there is always resistance to change and this takes time.
- Also, standards development is done by people volunteering their time, and unless there is a champion for a new standard or for a change, it will not likely take place.
- We often see the need but there are only a few of us working in this space

But like beavers we continue to work at it



Both ASTM Committees C01 and C09 welcome your participation

Thank you for Listening

Standards should enable innovation and not be a barrier to sustainable initiatives that will allow:

Less clinker in cement,

Less cement in concrete,

Less concrete in construction

Questions:

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