American Concrete Institute

Achieving Sustainability by Use of Alternative Cements

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Summary

- Historically, portland cement has been the primary choice, and in most cases the exclusive choice, for use as a binder in concrete for construction. As demands on all aspects of performance have increased, alternatives to portland cement have been developed and are increasingly in use. Alternative cements can often provide engineering performance that exceeds portland cement, while providing an improved environmental footprint. Conversely, for some applications, alternative cements may have attributes that make them unsuitable as a direct replacement for portland cement. This presentation will introduce currently available alternative cement technologies and discuss their sustainability aspects based on engineering performance and environmental footprint.

WHY ALTERNATIVE CEMENTS?

Performance Measures

- Environmental impact
  - Greenhouse gas emissions
  - Embodied energy

Performance Measures

- Life-cycle cost (LCC)
  - Total cost of ownership from cradle-to-grave or cradle-to-cradle
  - Planning, design, construction and acquisition, operations and user costs, maintenance renewal and rehabilitation, depreciation and cost of finance
  - Replacement or disposal costs
  - Durability
  - Initial cost

Performance Measures

- Functional Performance
  - Faster set times, rapid strength gain, low permeability, heat resistance, etc.
  - Demonstrated performance
  - Constructability

ALTERNATIVE CEMENT TECHNOLOGIES

Definition

alternative cement — an inorganic cement that can be used as a complete replacement for portland or blended hydraulic cements, and that is not covered by applicable specifications for portland or blended hydraulic cements.

Alternative Cement Classification

- Clinkered Alternative Cements
- Calcined Alternative Cements
- Nonclinkered Alternative Cements

CLINKERED ALTERNATIVE CEMENTS

Clinkered Alternative Cements

An alternative cement produced using technologies similar to portland cement production, with process changes that preclude production of portland cement but positively affect the environmental impact of production.

- Calcium aluminate cements (CAC)*
- Reactive belite cements (RBC)
- Calcium sulfoaluminate cements (CSA)*
- Carbonated calcium silicates (CCSC)

Calcium Aluminate Cements (CAC)

- Hydraulic cement
- Set: rapid compared to PC
- Strength: comparable to PC
- Key durability attributes: good sulfate, ASR, abrasion resistance
- Concerns: conversion reactions increase porosity and reduce strength over time, significant heat evolution
- Applications: refractory concrete, sulfate and acid resistance, rapid repair material
- Lower carbon footprint than PC

Calcium Sulfoaluminate Cements (CSA)

- Hydraulic cement
- Set: rapid and can be expansive
- Strength: high-early, slower rate of late strength gain compared to portland
- Key durability attributes: good sulfate, FT resistance
- Concerns: corrosion resistance, possible thaumasite formation
- Applications: non-reinforced structural, pre-cast, cold weather
- Lower carbon footprint than PC

CALCINED ALTERNATIVE CEMENTS

Calcined Alternative Cements

- An alternative cement produced by calcining a raw material only, without further pyroprocessing, to produce additional mineral phases within the material.

- Magnesium oxychloride cements (MOC)*
- Magnesium phosphate cements (MPC)*
- Magnesium ammonium phosphate (MAPC)
- Magnesium potassium phosphate (MKPC)

Magnesium Oxychloride Cement (MOC)

- Not a hydraulic cement
- Set: same or longer than PC
- Strength: high-early, late strength comparable to portland
- Key durability attributes: good fire, abrasion, ASR, FT resistance
- Concerns: loses strength when exposed to water at early ages, significant heat evolution, chloride corrosion
- Applications: patching, wallboard (Mag board)

Magnesium Phosphate Cement (MPC)

- Not a hydraulic cement
- Set: rapid set compared to PC
- Strength: low-early, moderate late strength compared to PC
- Key durability attributes: good sulfate, ASR, fire resistance
- Concerns: significant heat evolution
- Applications: fire-proof coatings, patching

NONCLINKERED ALTERNATIVE CEMENTS

Nonclinkered Alternative Cements

- An alternative cement produced using precursors that require no pyroprocessing and set after addition of an activating solution to cause reactions that are not hydration or acid-base.

- Alkali-activated fly ash cements (AAFA)*
- Alkali-activated slag cements (AAS)*
- Alkali-activated recycled glass cements (AAG)
- Supersulfated cements (SSC)*

Alkali-Activated Fly Ash Cement (AAFA)

- Not a hydraulic cement
- Set: rapid
- Strength: high-early, late strength comparable to PC
- Key durability attributes: good sulfate, acid, ASR, fire resistance
- Concerns: performance varies with fly ash source
- Applications: same as PC

Alkali-Activated Slag Cement (AAS)

- Not a hydraulic cement
- Set: same or faster than PC
- Strength: low-early, late strength comparable to PC
- Key durability attributes: good sulfate, corrosion, acid, ASR, fire, resistance
- Concerns: performance varies with slag source
- Applications: same as PC

Supersulfated Cement (SSC)

- Blast furnace slag activated by means of calcium sulfate
- Not a hydraulic cement
- Set: same or faster than PC
- Strength: low-early, late strength comparable to PC
- Key durability attributes: good sulfate resistance, low heat of hydration
- Concerns: limited field experience
- Applications: same as PC
- Lower carbon footprint than PC

Testing Requirements

- Alternative cements often cannot meet current PC specifications due to:
  - A significantly different composition
  - Different sample preparation or curing needs for testing
  - Other limits imposed by the test methods specified

Challenges

- Current test methods were developed for PCC
- Specimen preparation largest single issue
  - Specific mixing procedures
  - Specific curing procedures
- Correlation between laboratory tests and field performance
- Coordination with ASTM

Report on Alternative Cements

- Background and drivers for alternative cements
- Technical information on AC technologies
  - Clinkered ACs
  - Calcined ACs
  - Non-clinkered ACs
- Testing requirements for AC technology
  - Current situation
  - Needs

Practitioner's Guide

- Summary of technical document
- Case studies
- Guidelines for use – what questions to ask?
  - Mixture design
  - Construction
  - Design properties

Committee Goals

- Determine a name for these cements other than Alternative Cements. The term “alternative” by itself limits adoption and it is not descriptive.
- Define the distinction between alternative cements and alternative supplementary cementitious materials
- Develop a more in-depth state-of-the-art report based on the ITG Final Report and Practitioners Guide.

Committee Goals

- Develop TechNotes on each individual AC technology
- Assemble additional case studies; serve as the clearinghouse for disseminating information on AC use world-wide
- Interface with the SDC, RILEM, ASTM to facilitate development of necessary specifications and tests
- Develop a performance-based guide specification for ACs

ACI 242 – ALTERNATIVE CEMENTS

Tuesday, October 16 from 12 – 3pm at the Rio Pavilion 10

MINI SESSION 12 – 1pm

“Recent Advances in Alternative Cements”

THANK YOU.

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