American Concrete Institute®
Advancing concrete knowledge

Emerging Technologies in the Concrete Industry

ACI Fall 2012 Convention
October 21 – 24, Toronto, ON

ACI
WEB SESSIONS

James K. Hicks, P.E. Education: B.S., Chemistry, Oklahoma; Graduate School, Business, University of California; Technical diploma, Computer Programming, New Mexico. Developed rapid hardening cements, masonry cements, specialty cements and cement products with over 90% activated fly ash as the main constituent. Developed numerous new cements and associated products for the commercial market. Represents company with leadership roles in ASTM, ACI, USGBC, ICRI, CSI and other organizations. Over 35 years experience in management of cement and concrete product development/technical service, process engineering, marketing/sales engineering, quality assurance/quality control and plant management with such firms as CeraTech, Mineral Resource Technologies-CEMEX, QUIKRETE, Lafarge, Blue Circle and others. Managed and engineered domestic and international cement plants. Developed the first Type IP fly ash - portland cement and product blends in several states beginning in 1973. Earned US and International patents in fly ash-based rapid hardening cements, masonry cements and cement products. Delivered numerous presentations in cement, product technology and process control. P. E. Texas, California.

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Green Cements; Changing the Foundation of th Cement Industry

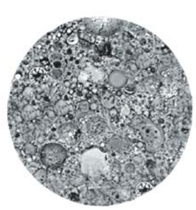
Largely:
- *Activated Fly Ash*
- *Activated Slag*
- *Calcium Sulfo Aluminate*
- *Calcium Aluminate*
- *Activated Glass*
- *Geopolymers*
- *Magnesia Phosphate*

Activated Class C Fly ash

Technology Overview

Pozzolan based cement system comprised of a pozzolan powder and proprietary admixtures

Combination produces a dense crystal structure comprised principally of calcium silico-aluminate hydrates



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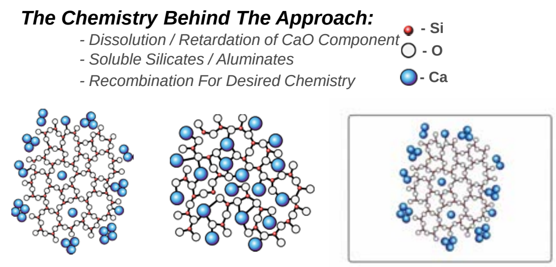
Cement Science

The Chemistry Behind The Approach:
- *Dissolution / Retardation of CaO Component*
- *Soluble Silicates / Aluminates*
- *Recombination For Desired Chemistry*



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BULK Goods

General Use Cement:

General Use
To High Performance
Cement

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BULK Goods

Admixtures:

Base Activators:

ba100
ba200

Modifiers :

m300
m400

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Key Performance Characteristics

Mechanical:

Compressive Strengths

30% of 28 Day Strengths in 3 Days

80% of 28 Day Strengths in 7 Days

Flexural Strengths

20% of Compressive Strengths

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Key Performance Characteristics

Dimensional:

Length Change

< 1/16th of an inch over 10 feet

Coefficient of Thermal Expansion

4.7×10^{-6}

Heat of Hydration

30% less total heat than OPC

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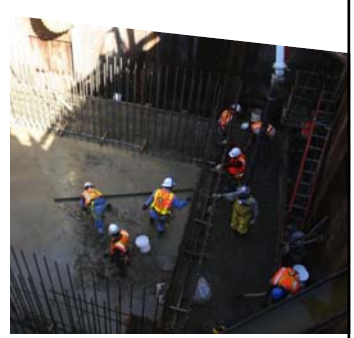
Key Performance Characteristics

Durability:

- ***Chemical Resistant***
- ***Freeze Thaw Resistant***
- ***Scaling Resistant***
- ***Abrasion Resistant***
- ***Corrosion Resistant***
- ***ASR Resistant***

ekkomaxx™ Cement Concrete Attributes

- ***Work-ability***
- ***Finish-ability***
- ***Pump-ability***
- ***Set-ability***



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Material Technology Value Proposition

- **Robust Material System**
  - Concrete performance controlled by admixtures
- **Cost Competitive**
- **Sustainable,** (Carbon Neutral Cement)
  - Produced from 95% waste material & 5% rapidly renewable resources
- **Exceptional Durability**
  - Produces an extremely dense cement matrix with low permeability and a discontinuous pore structure
  - No excess calcium hydroxide

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Material Technology Value Proposition

- **Superior Mechanical & Dimensional Properties**
- **Material is Mixed, Placed and Finished Like OPC**
- **Drops Into Current Industry Distribution Network**

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Mix Design
Typical General Use Concrete

Mix Design

Component	SpG	Lbs (gal)/ cuyd	Abs. Volume	Source
C Ash	2.770	513.6	2.971	
F Ash	2.290	86.4	.605	
CA (SSD)	2.598	1629	10.050	
FA (SSD)	2.611	1452	8.913	
Water	1.000	149 (17.8)	2.388	
BA 100	1.355	31.40 (2.78)	.371	CTI Proprietary
M 300	1.328	6.80 (.61)	.082	CTI Proprietary
Control 40		68 oz		Sika
Air	6.0 %	11 oz	1.620	BASF Micro air
Total		4059.8	27.000	W/C Ratio:.27

Strengths:	24 hours	2 day	7 days	28 days
	1200 psi	2100 psi	3700 psi	6000 psi

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Mix Design
Typical Specialty Use Concrete

KEMROK™

Mix Design

Component	SpG	Lbs (gal)/ cuyd	Abs. Volume	Source
C Ash	2.770	715	4.136	Big Cajun
F Ash	2.290	52.6	.366	Boral
Component C	2.970	40	.215	CTI Proprietary
CA (SSD)	2.674	1800	10.737	Martin Marietta
FA (SSD)	2.615	1281	7.799	Fordyce
Water	1.000	167.3 (20)	2.681	Galveston City
Air	1.5%		.405	
Liquid Activator	1.340	64.4 (5.75)	.661	CTI Proprietary
Total		4120.3	27.000	W/C Ratio:.22

Strengths:	24 hours	2 day	7 days	28 days
	2100 psi	3500 psi	6050 psi	8000 psi

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Case Study - Roller Compacted Concrete (RCC)
SAVKO Columbus, Ohio

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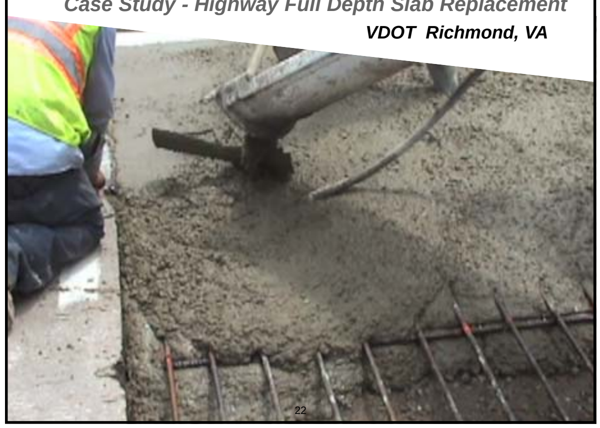
Case Study - Highway Full Depth Slab Replacement
VDOT Richmond, VA



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Case Study - Warehouse Foundation & Slab

USMC Bridgeport, CA

QuickTime™ and a
DV/DVCPRO - NTSC decompressor
are needed to see this picture.

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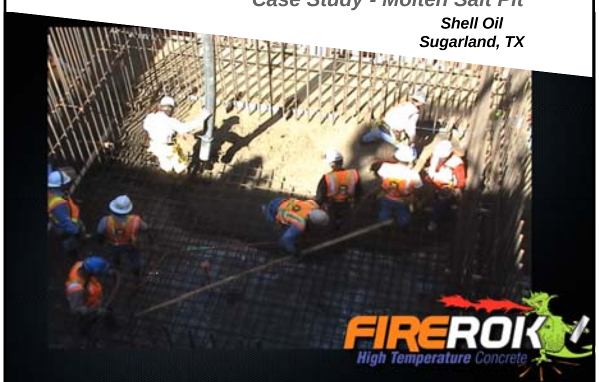
Case Study - Molten Sulfur Flume

Savage Sulfur Processing
Galveston, TX

Case Study - Molten Salt Pit

Shell Oil
Sugarland, TX



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Case Study - Precast Concrete Manhole

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Other Major Green Cements

- Calcium Sulfo Aluminate (CSA)
- Calcium Aluminate (CA)
- Activated Glass (AC)
- Magnesia Phosphate
- Geopolymers

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Calcium Sulfo Aluminate (CSA)

Commercial sulfoaluminate clinkers developed by the Chinese predominantly consist of $C_4A_3\bar{S}$ (55–75%) (also known as Klein's compound) and a-C_2S (15–25%). The remaining phases present are $C_{12}A_7$, C_4AF and CaO.

Belite (C_2S)-rich sulfoaluminate cements are preferred to alite (C_3S)-rich, since belite-based cements can be formed at around 1200 C, as opposed to 1400 C for the alite cements. This equates to an energy savings of 20% during manufacture(Popescu, et.al.) and results in less CO_2 being generated from the reaction of formation of C_2S compared to C_3S.

Cements containing larger quantities of C_2S than C_3S are less permeable as well as being more resistant to chemical attacks and smaller drying shrinkage.

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Calcium Aluminate (CA)

CAC's were invented in the early 1900's to resist sulfate attack.

CAC's are inherently rapid hardening and can be rapid setting, adjustable with appropriate chemical admixtures.

These cements are often used in refractory applications, building chemistry and rapid repair, rehabilitation and construction of concrete flatwork (e.g. sidewalks, overlays and full-depth pavement construction).

The rapid hardening properties, resistance to sulfate attack and alkali-aggregate reaction and abrasion resistance make these cements desirable in a wide-range of special applications.

The manufacturing process of CAC's generates significantly less CO_2 than the ordinary portland cement (OPC); roughly on the order of 50% less.

The most widely discussed and controversial aspect of CAC's is a process referred to as conversion. Conversion is a process where metastable hydrates (CAH_{10} and C_2AH_8) formed at low and moderate temperatures (T=5 to ~70°C) convert to stable hydrates (C_3AH_6) formed at high temperatures (T>70°C). This process leads to an increase in porosity and subsequent decrease in strength. Conversion is an inevitable process and must be accounted for when designing the concrete mixture.

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Magnesia phosphate cements:

Synthesized by reacting magnesium oxide with a soluble phosphate (e.g. ammonium phosphate). In essence, this is an acid–base reaction between the phosphate acid and the magnesium oxide to form an initial gel that crystallizes into an insoluble phosphate, mostly in the form of magnesium ammonium phosphate hexahydrate ($NH_4MgPO_46H_2O$).

Magnesia phosphate cements are characterized by very high early strength and rapid setting, which makes them useful as a rapid patching mortar. It can also bind well to a wide variety of aggregates and substrates. Unlike magnesium oxychloride and oxysulfate cements, this cement has good water and freeze-thaw resistance and is, therefore, amenable to a wide variety of applications. A major drawback, however, is the expensiveness of phosphate, which confines its application to niche areas.

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Recycled Glass-based Cements and Concretes:

Due to a high concentration of amorphous silica (~70% wt.) soda-lime glass can react pozzolanically with portlandite in a glass-portland cement system and produce low Ca/Si C-S-H. At moderate (up to 30%wt.) replacement levels of OPC, glass powder has been found to improve compressive strength beyond 28 days; however, early strengths can be reduced when using the same w/cm.

Fineness of glass powder has a significant impact on its reactivity; glass finer than 38µm satisfies the strength activity index of ASTM C 618 (SAI>75% at 7days) and can be classified as a Type N pozzolan. By further increasing glass fineness and/or heat curing, concretes with 3-day strengths surpassing that of OPC concrete can be prepared. In addition, fine glass powder (<10µm) can mitigate the alkali-silica reaction generated by glass aggregates or other natural reactive aggregates

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