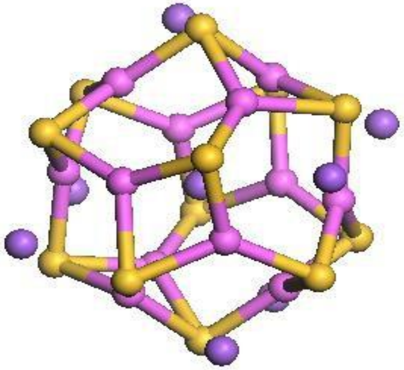
LOUISIANA TECH UNIVERSITY
COLLEGE OF ENGINEERING AND SCIENCE

"Geopolymer concrete (GPC): A new generation high corrosion resistance cementitious binder for the manufacture of precast pipe and manholes"



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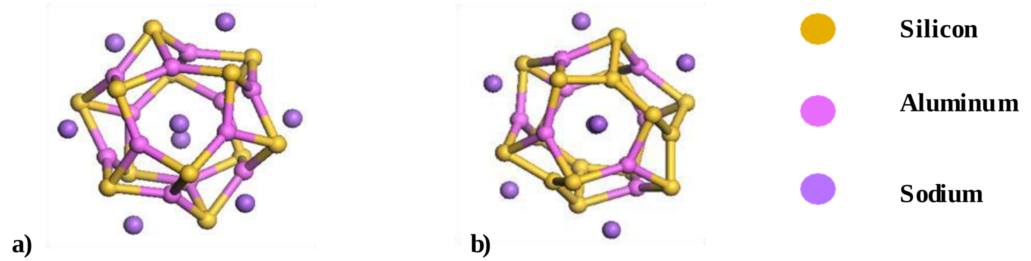
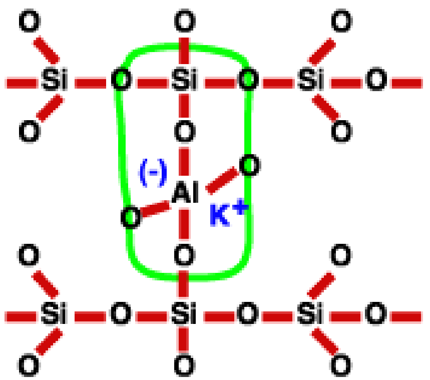
GEOPOLYMER BASICS

- Geopolymers are inorganic polymers which are the result of a condensation process.

- Geopolymers are formed by a 3D network of Si & Al mineral molecules linked through covalent bonds with oxygen molecules.



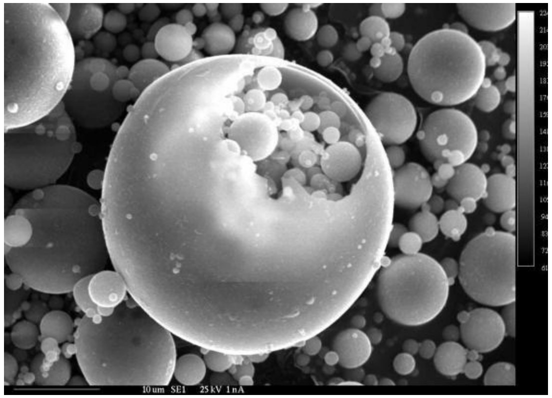


GEOPOLYMER PRECURSORS

- The most important source material for geopolymers is fly ash, for commercial and performance reasons.

- It is activated with a chemical solution and in some cases with a slightly elevated temperature is required to start the geopolymerization reaction.

FLY ASH DESCRIPTION



- Fly ash is the finely divided mineral residue resulting from the combustion of coal.
- Fly ash material is solidified while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags.
- **Since the particles solidify while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 100 µm.**
- **They consist mostly of silicon dioxide (SiO2), aluminum oxide (Al2O3) and iron oxide (Fe2O3), and are hence a suitable source of aluminum and silicon for geopolymers.**
- They are also pozzolanic in nature and react with calcium hydroxide and alkali to form cementitious compounds.

Geopolymer paste can be combined with the same aggregates used for Portland cement, for its use as mortar or concrete.

The activator solution may then be added to the powdered fly ash in the same way as water is added for Portland cement and mixed with conventional equipment (e.g., gravity mixers).

There applications are, for example, heat insulation panels, storage of corrosive substances, exposure to saline or aggressive environments on where Portland cement concrete needs to be replaced often.

Geopolymer's excellent mechanical and long term properties greatly exceed those of Portland cement for applications where a high corrosion resistance cementitious binder is required.

Significance of the Research – State of Louisiana

Louisiana is one of only 5 states in the USA that does not have an 'in-house' cement industry – all the cement used in Louisiana is imported from neighboring states.

About 8 million tons of fly ash are produced annually within 8 hrs drive of Baton Rouge

Louisiana have a bridge inventory of nearly 5000 structures, many of which are located in aggressive marine environments

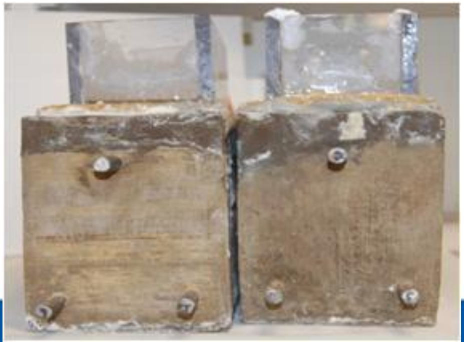
The most likely source of renewable energy for Louisiana is the incineration of biomass




Potential Benefits of Geopolymer Binder Technology to Louisiana

The establishment of a pre-cast facilities that use Louisiana's fly ash to build Louisiana's infrastrucutre (e.g., a geopolymer precast facility in Desoto Parrish in collaboration with Cleco

Geopolymer Concrete offers a 8 time higher corrosion resistance compared with Portland Cement concrete (~250 yr design life)



GEOPOLYMER FAVORABLE CHARACTERISTICS

- Strong - High overall compressive strength (up to 100 MPa).
- Fast - Within 24 hours exceeds OPC 28 day cured strength.
- Corrosion Resistant – High sulfate, salt and acid resistance.
- Low Permeability – Lower fluid transfer/less chemical migration than concrete.
- Fire Resistant – Geopolymer endures temperatures to 2700° F (1500° C) without changing its basic matrix.
- Green Appeal – Environmentally and economically attractive.

The reason geopolymer binders exhibit superior performance compared with Portland cements in terms of corrosion and fire resistance is because they have no WATER and no CALCIUM in their structure

.

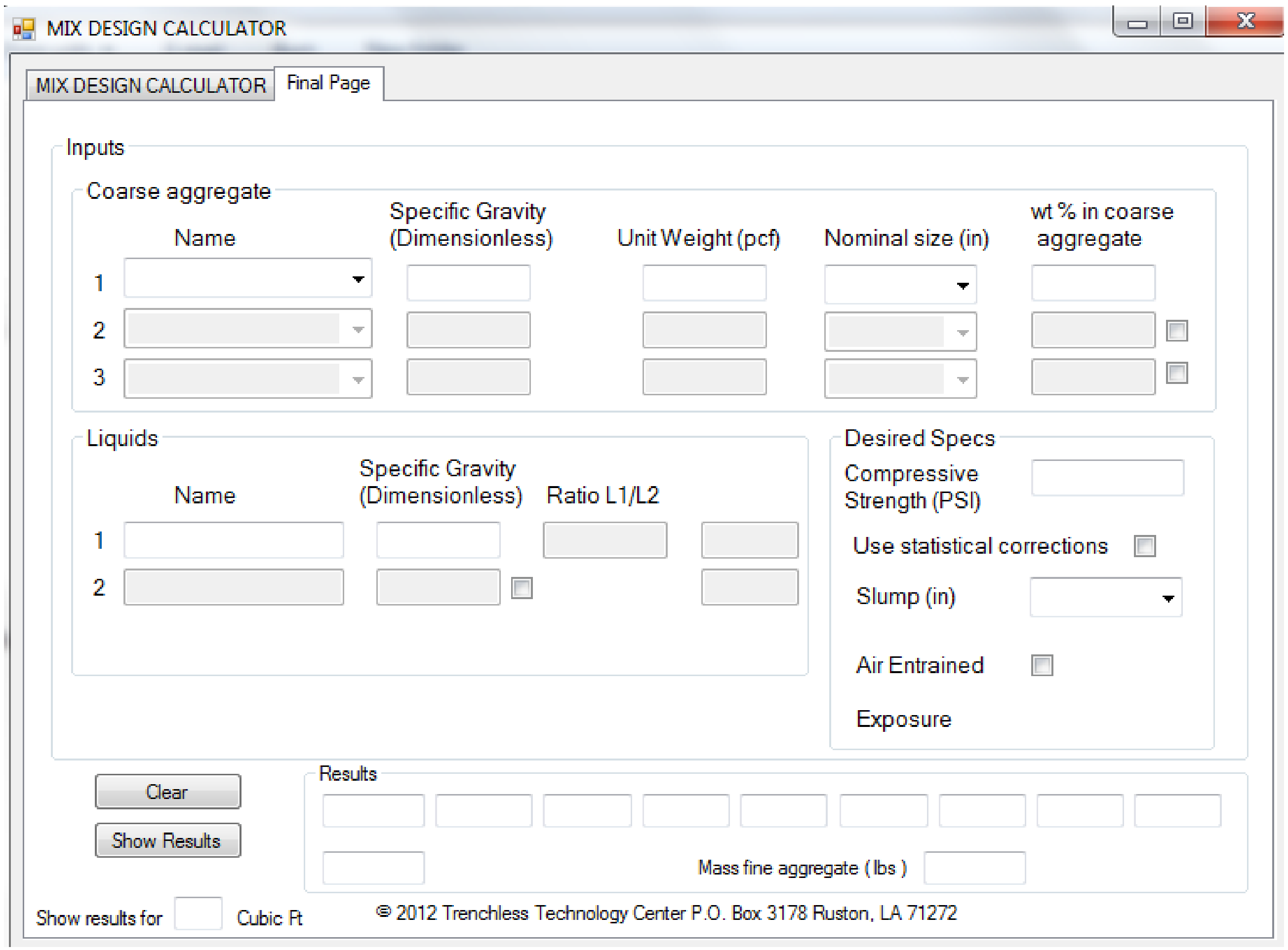
GENERAL IDEA TO DEAL WITH FLY ASH VARIABLE COMPOSITION

- Cement companies possess automated control systems to overcome the variability of the raw material chemical compositions and produce a material with constant quality.

- The same automated control systems can be used to overcome the variability behind fly ash chemical characteristics to produce geopolymer with characteristics within an acceptable range.

Proportioning, Blending & Grinding

GEOPOLYMER MIX DESIGN SOFTWARE



GEOPOLYMER MIX DESIGN AND PROPORTIONING

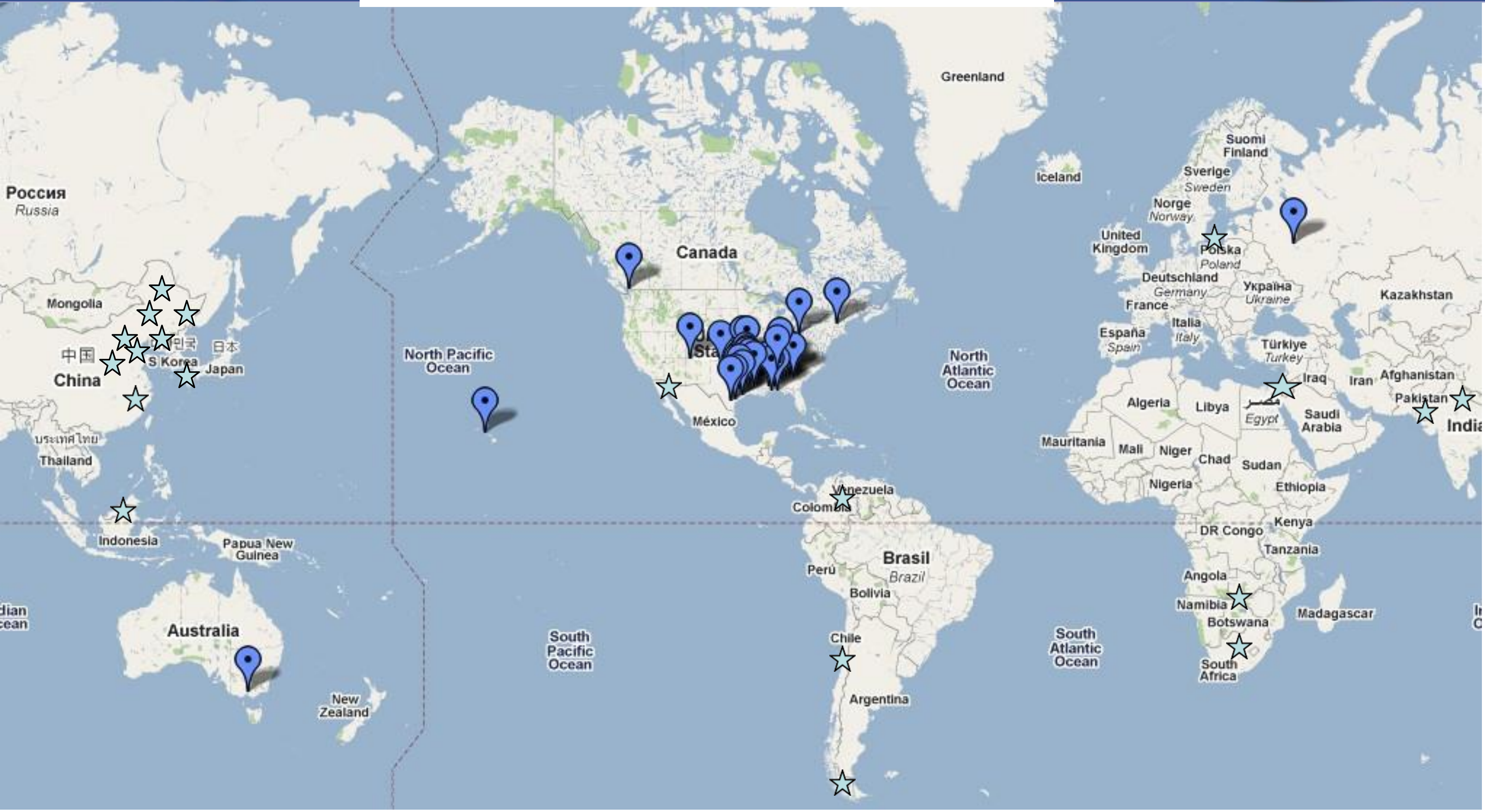
- Geopolymer concrete mix designs can be obtained using the ACI 211.1 guideline with certain modifications.

- The Trenchless Technology Center of Louisiana Tech has developed a mix design software to account for the extra variables related to GPC mix design formulation.

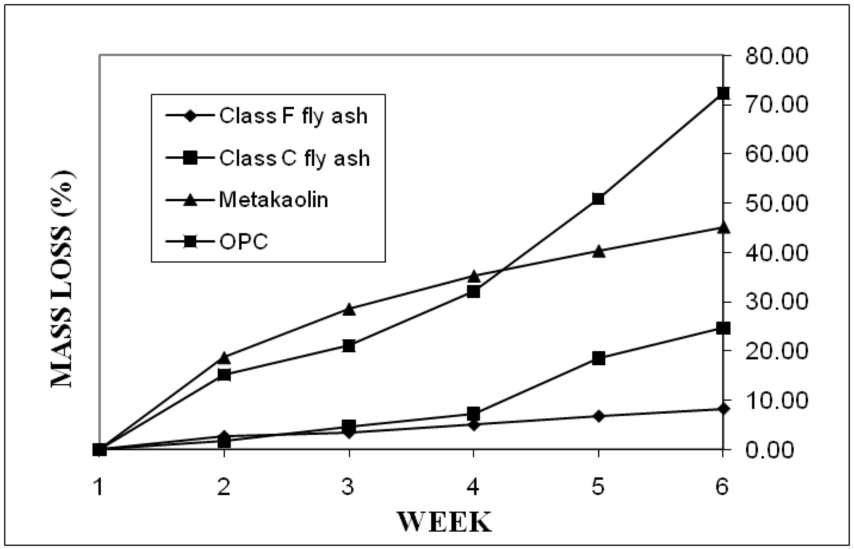
- Geopolymer concrete can be designed for compressive strengths ranging from 2,000 to 16,000 psi, slumps from 0 to self leveling and different exposure conditions including freeze-thaw, corrosive environments and elevated temperature/fire.

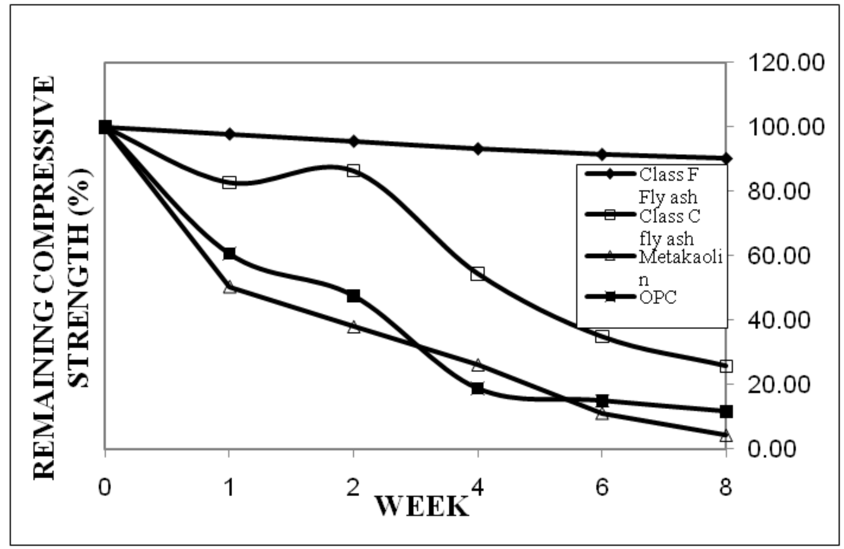
Creation of a Database

Location of Fly Ash Sources



GEOPOLYMER CORROSION RESISTANCE

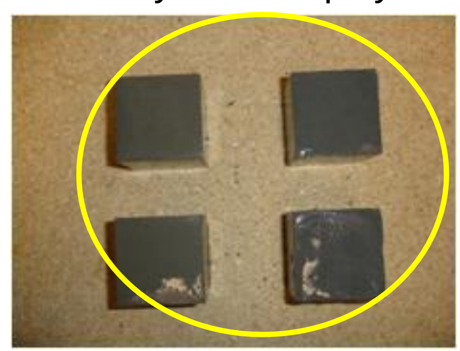




Ordinary Portland Cement

Class C fly ash Geopolymer

Class F fly ash Geopolymer



The geopolymer and Portland cements in the yellow circle were tested according to ASTM C-267. They were exposed to a 6% sulfuric acid solution for 8 weeks.

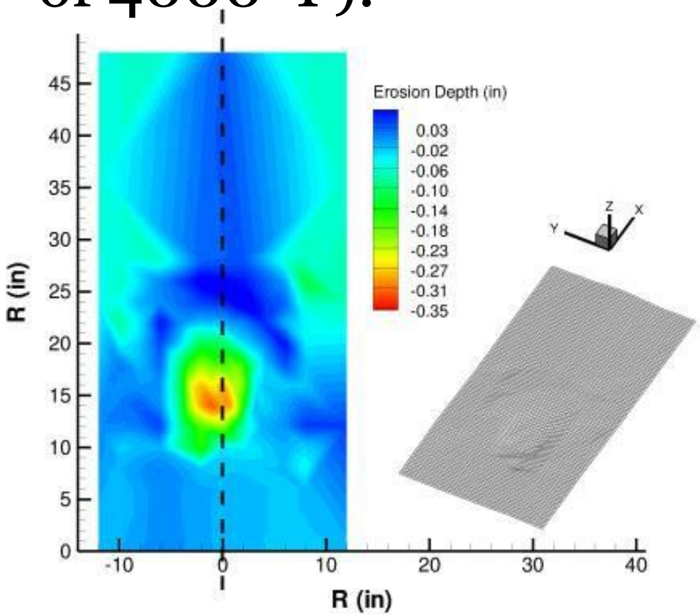
GEOPOLYMER POUR AT LOUISIANA TECH

Pilot Project #1
Installation of Test Patch in Test Cell E1
NASA Stennis, MS

Test patch for
Geopolymer Concrete

GEOPOLYMER TESTING AT NASA STENNIS

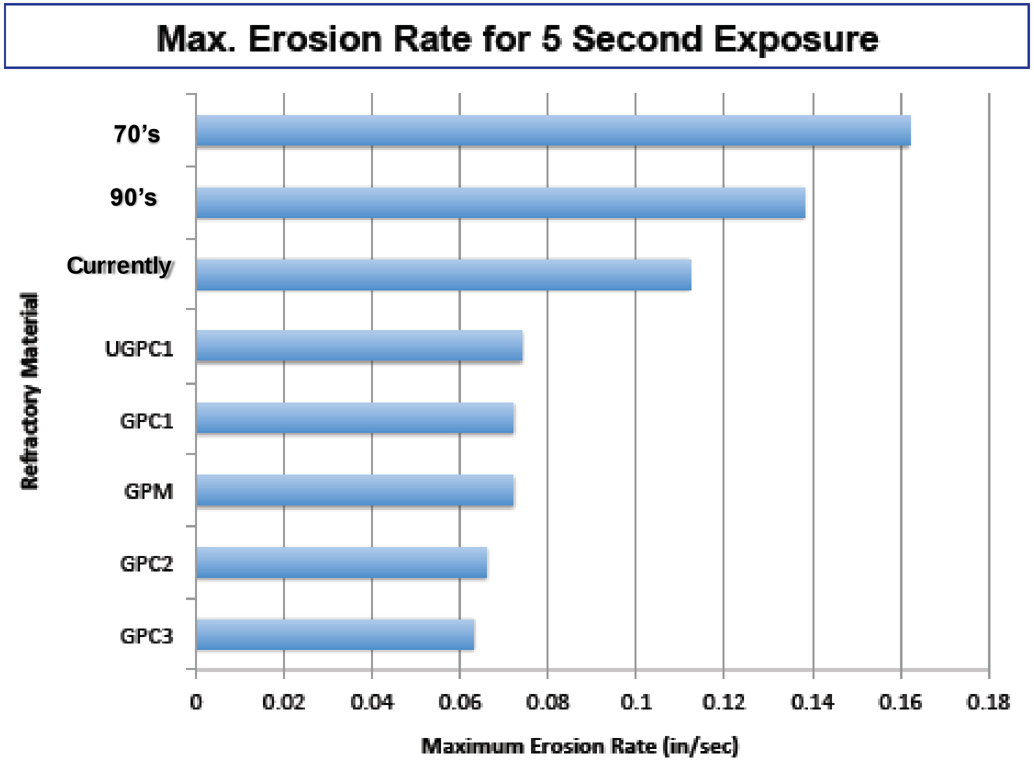
Tests conducted at the NASA Stennis Space Center demonstrated geopolymer erosion rates of roughly half of commercial refractory products when exposed to a flame of 4000˚F).



Summary of Refractory Material Performance

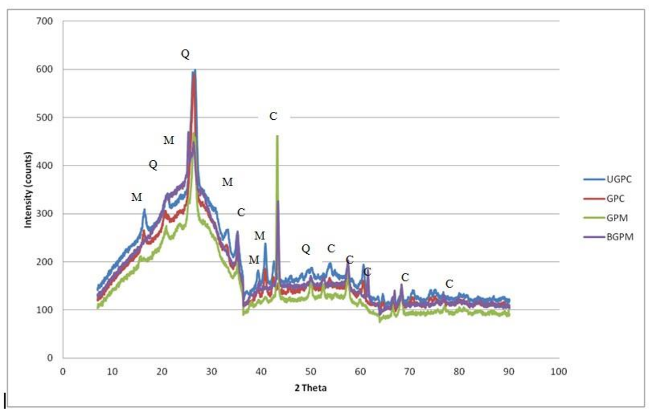
Short Duration Test Data (5sec)

- All Geopolymer formulations outperformed commercial refractories
- Geopolymer performance was not very sensitive to formulation.



Project #2 – Future building on the moon

Geopolymerized lunar regolith (Lunamer)



Characteristics of Ge opolymer Concrete

Test	ASTM Standard	Typical Values/ Properties
Mechanical Properties		
Compressive Strength*	C-39	80 MPa (11,600 psi)
Flexural Strength	C-78	7.4 MPa (1,073 psi)
Elastic Modulus	C-469	43 GPa (6,236 ksi)
Poisson's Ratio	C-469	0.11-0.22
Bond Strength	D-4541	9.6 MPa (1,400 psi)
Setting Time	C-403	25 - 600 minutes
Percent Absorption	C-642	2%-8%
Density	C-642	1800 - 2350 kg/m^3 (110 - 146 lb/ft^3)
Abrasion Resistance		Very Good, 8 cm
Durability of Geopolymer Concrete		
Corrosion Rate when subjected to one year of saltwater exposure	G-02	0.09 $\mu A/cm^2$
Chloride Diffusion Coefficient	C-1556	$1.45x10^{-12}$ m^2/s
% Expansion due to Alkali Silica Reaction (ASR)	C-1260	Min: 0.04 % Max: 0.1%
Sulfate attack		Stable in 5 % solution of $NaSO_4$ & $MgSO_4$
Corrosion Resistance	C-267	High level of resistance to a range of acids and salt solutions (Na2SO4, MgSO4, NaCl, Sulphuric Acid, Hydrochloric Acid)
Temperature		Thermal Stability up to 3200°F
Thermal Conductivity		~0.2-0.3 W/m/K

Pilot Project #3 **GEOPOLYMER PRECAST PIPES (LEHIGH-HANSON / HEIDELBERG CEMENT)**

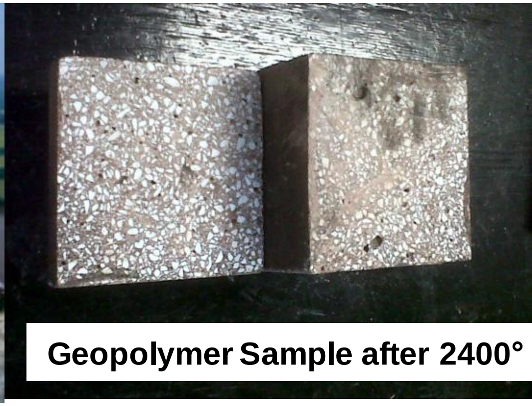
Pre-cast geopolymer pipe subjected to D-load at a commercial manufacturing facility; the pipe tested to 9,200 psi, surpassing that design load of 8,000 psi.

Project #4 - Pulp and Paper Facility, MS

Using geopolymer for the repair of several sulfuric acid corrosion-exposed areas including manholes in their sealed-sewer system , chemical unloading areas, and areas adjusted to the boiler system.

TTC partnered with ML Smith to perform this project. A total of 7 cu. yd.

Project #5 - Kyger Creek Power Generation Station, OH (*American Electric Power/EPRI*)



Development and testing of a high temperature geopolymer formulation for flooring of coal burning furnaces. Specific challenge - development of a formulation that withstands the diffusion of slag into the matrix.

Current geopolymer formulations holds up to 2400° F. Research to expand it to 2800-3200° F.

Project #5 - Kyger Creek Power Generation Station, OH (*American Electric Power/EPRI*)

Project #6 - National Security Technologies, NV

National Security Technologies has partnered with the TTC for the installation of the largest to-be geopolymer sidewalk in North America.

The size of the project is about 65 cy (**133 tons**), making it the largest geopolymer pour ever in North America.

TTC has conducted an extensive research project to produce an optimal formulation (flowability, setting time, mechanical strength, finishability, ambient cure).

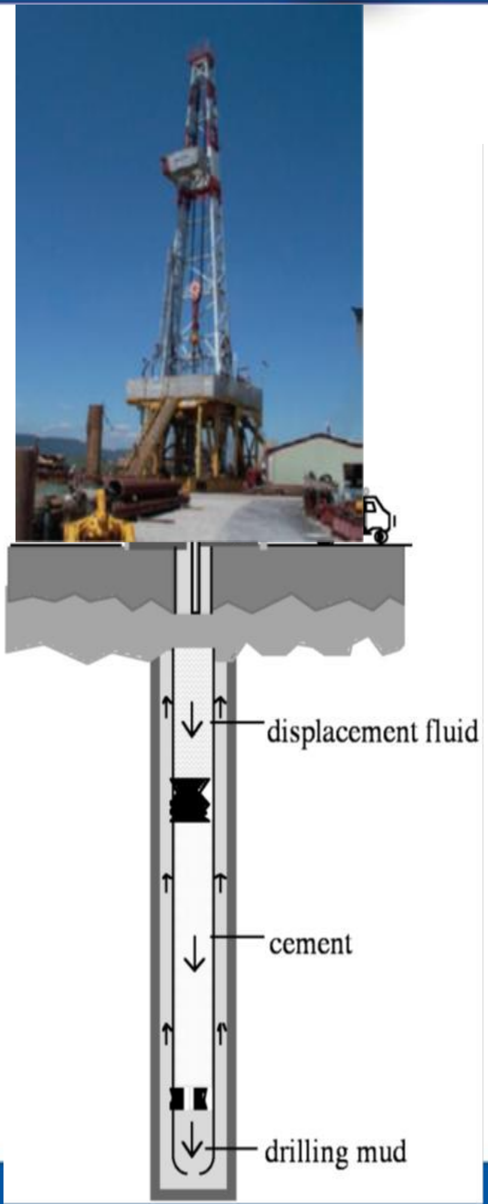
Project #7 – Dry-cast pavers and bricks

Project #8 - '<u>Programmable</u>' Geopolymer Casing Grout for 'Tight' Oil & Gas Wells

- Tight oil, gas and shale wells, enabled by horizontal drilling and fracking technologies, represent the future of the US energy market and a path for <u>energy independence</u>

- Key barrier is the lack of dependable casing grouting materials for deep wells, potentially compromising shallow aquifers (<u>*5% of casing fail upon completion; 50% within well service life*</u>)

- We should <u>not</u> need to choose between cheap energy and clean water !!!

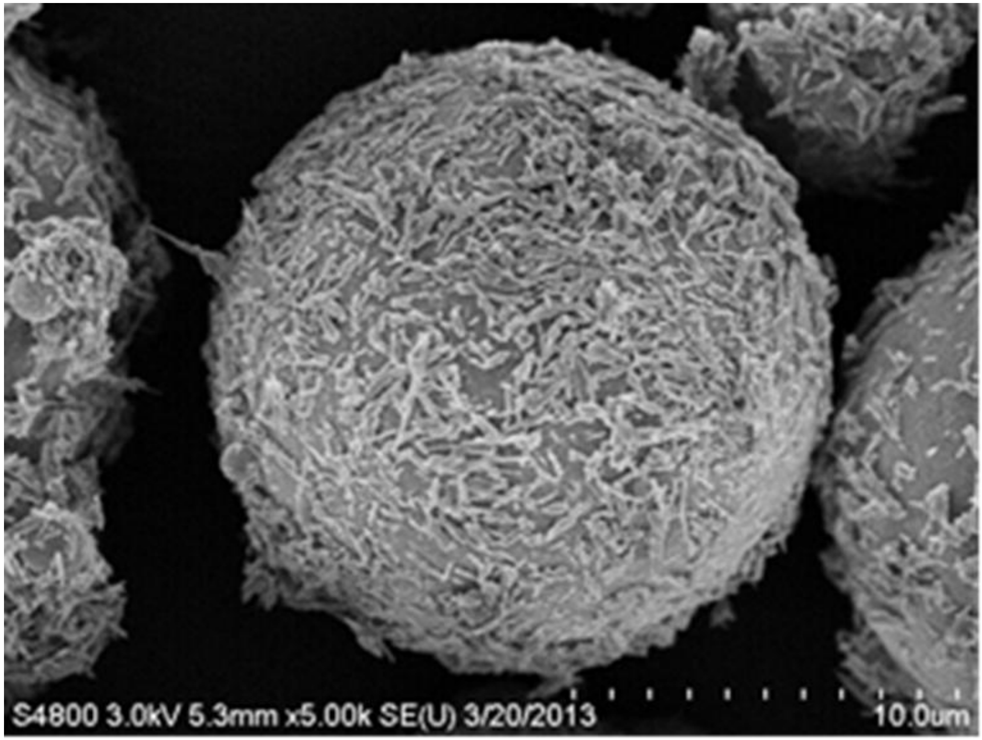


Next Generation Cementitious Materials

- Combination of geopolymer binder technology and nano-technology

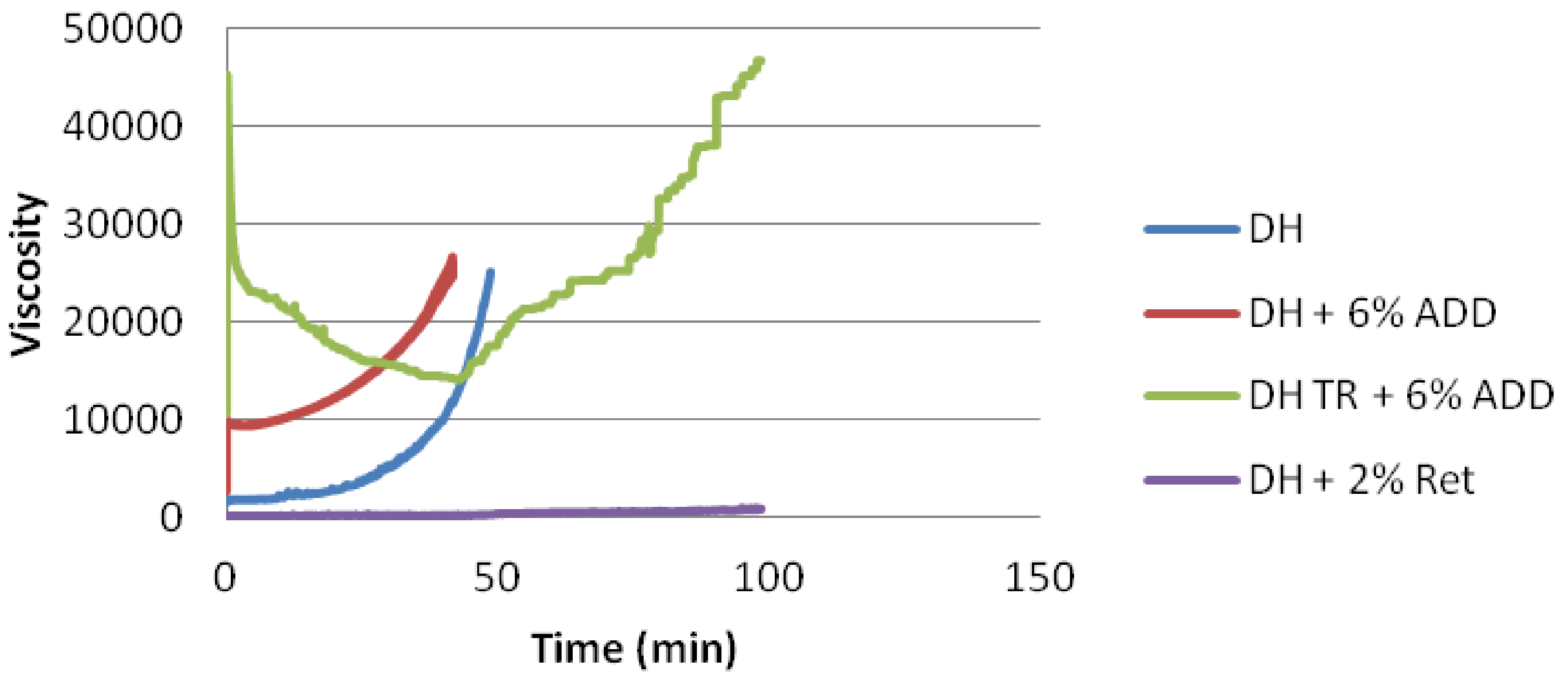
- ‘Programmable Particles’ capable of highly controlled rheological behavior across multiple pressure and temperature zones as a function of time

- Piezoelectric characteristics (electro-elasto-mechanical deformation of crystals phases) enable remote inspection of casing integrity



Binder granular coated with ‘delay-action’ nano-particles

Dolet Hills geopolymer viscosity at 50 C

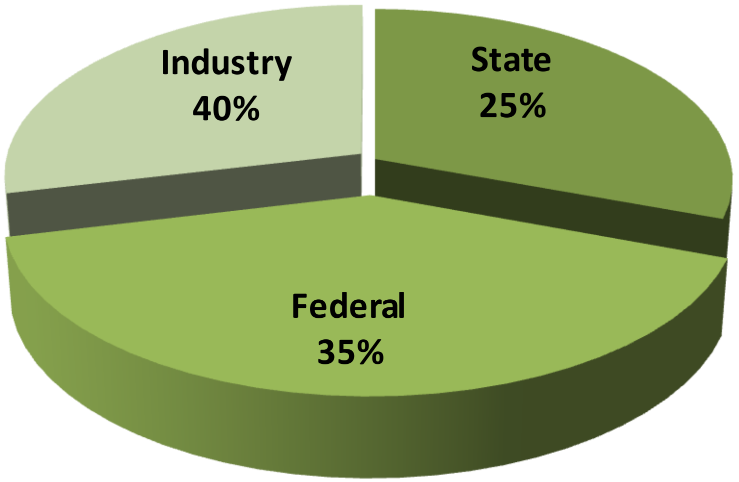


HT-GEOPOLYMER CONCRETE – LOUISIANA PRODUCT OF THE YEAR – LOUISIANA TECHNOLOGY COUNCIL

Baton Rouge, LA Sept 19th, 2012

Summary of funded projects

- 30 Funded Projects
- 7 State Funded Projects
- 5 Federally Funded Projects
- 16 Industry Funded Projects



Commercial License & Business Development Partner

AGS

Alchemy Geopolymer

SOLUTIONS

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