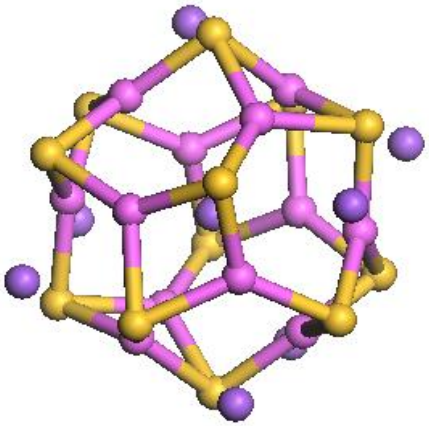
High Durability "Green" Inorganic Polymer Binders for Sustainable Construction

Sponsored by Louisiana EPSCoR-OPT-IN Program



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What are Geopolymer Binders?

- **Geopolymer Binders** are an emerging class of cementitious material that can be manufactured from industrial byproducts, such as fly ash, that can be used as 100% replacement for Portland cement in construction applications:
- **High compressive and tensile strengths**
- **High resistance to chemical attack and elevated temperature (geopolymers are low order ceramics)**
- **Low energy consumption**
- **Low carbon footprint**
- **Enhanced environmental benefits and cost reduction**

Objective

Develop an understanding of the mechanical and rheological properties of geopolymer binders at the atomistic, micro-structure and macro-structure in support of the development of selected commercial applications

Significance of the Research – Global Prospective

Concrete is the 2nd most used processed material in the world by weight after water

Annual global consumption of concrete is 20 billions tons per year, 3 ton per every person on earth; Market value ~ $1.8 trillion

Actual production of Portland cement contributes 3.6 billion tons of CO_2 per year (1 ton of CO_2 for each ton of cement produced) which is equivalent to **7%** of the total global emission of CO2 to the atmosphere.

Geopolymer binder technology offer a 100% 'green' replacement to Portland cement, with 85% reduction in carbon footprint and 90% in energy consumption

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

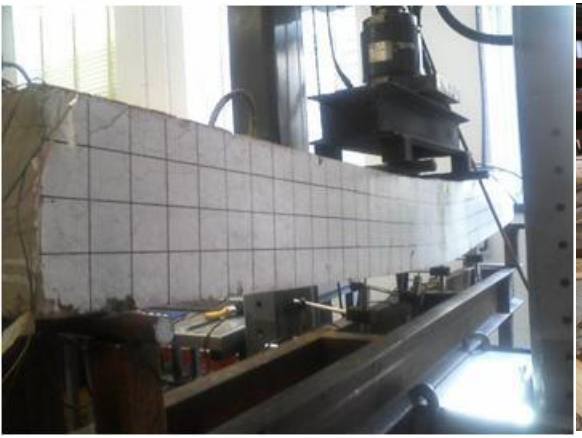
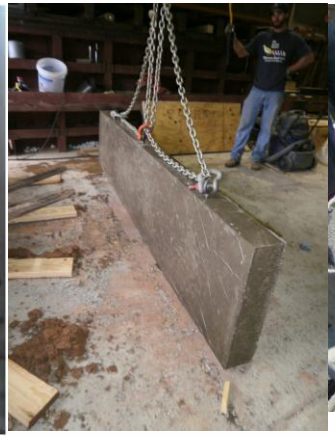
Louisiana have a bridge inventory of nearly 5000 structures, many of which are located in aggressive marine environments

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

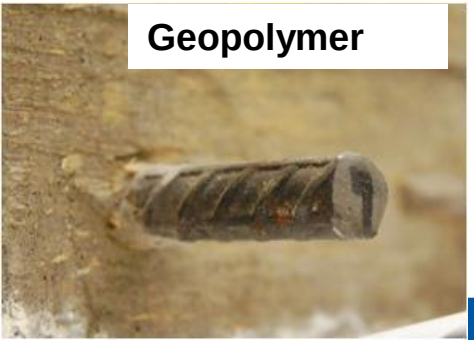


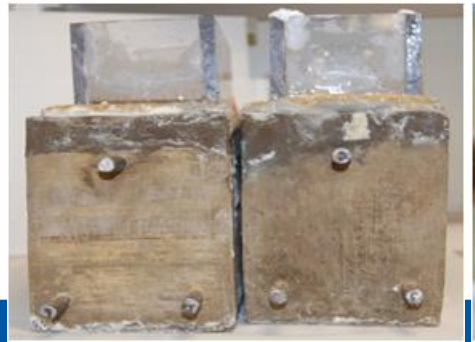

Potential Benefits of Geopolymer Binder Technology to Louisiana

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

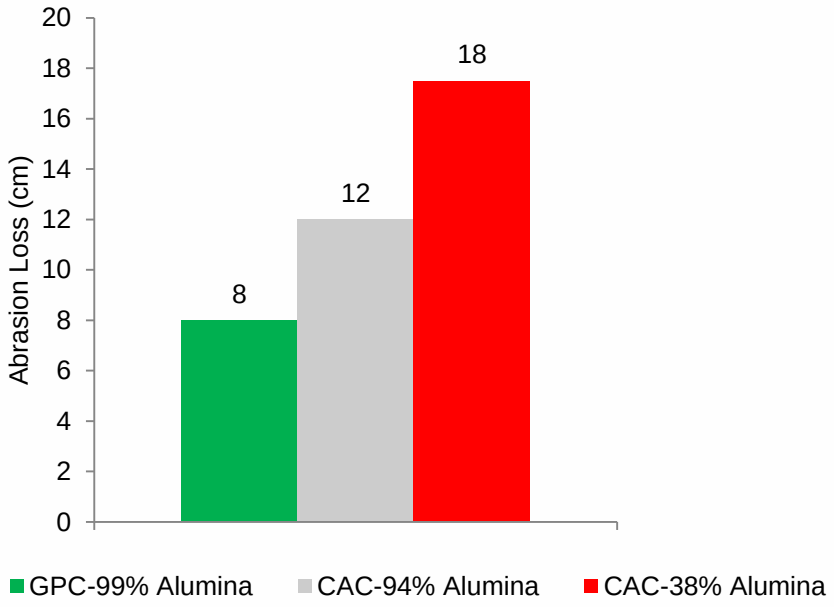
Geopolymer Concrete offers a 8 time higher corrosion resistance compared with Portland Cement concrete (~250 yr design life)





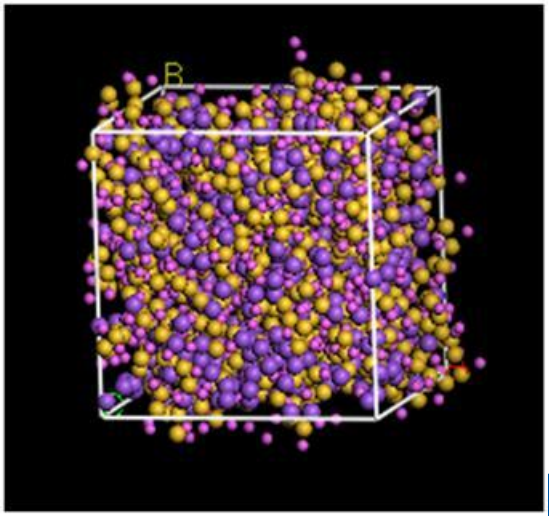

Potential Benefits of Geopolymer Binder Technology to Louisiana (Cont')

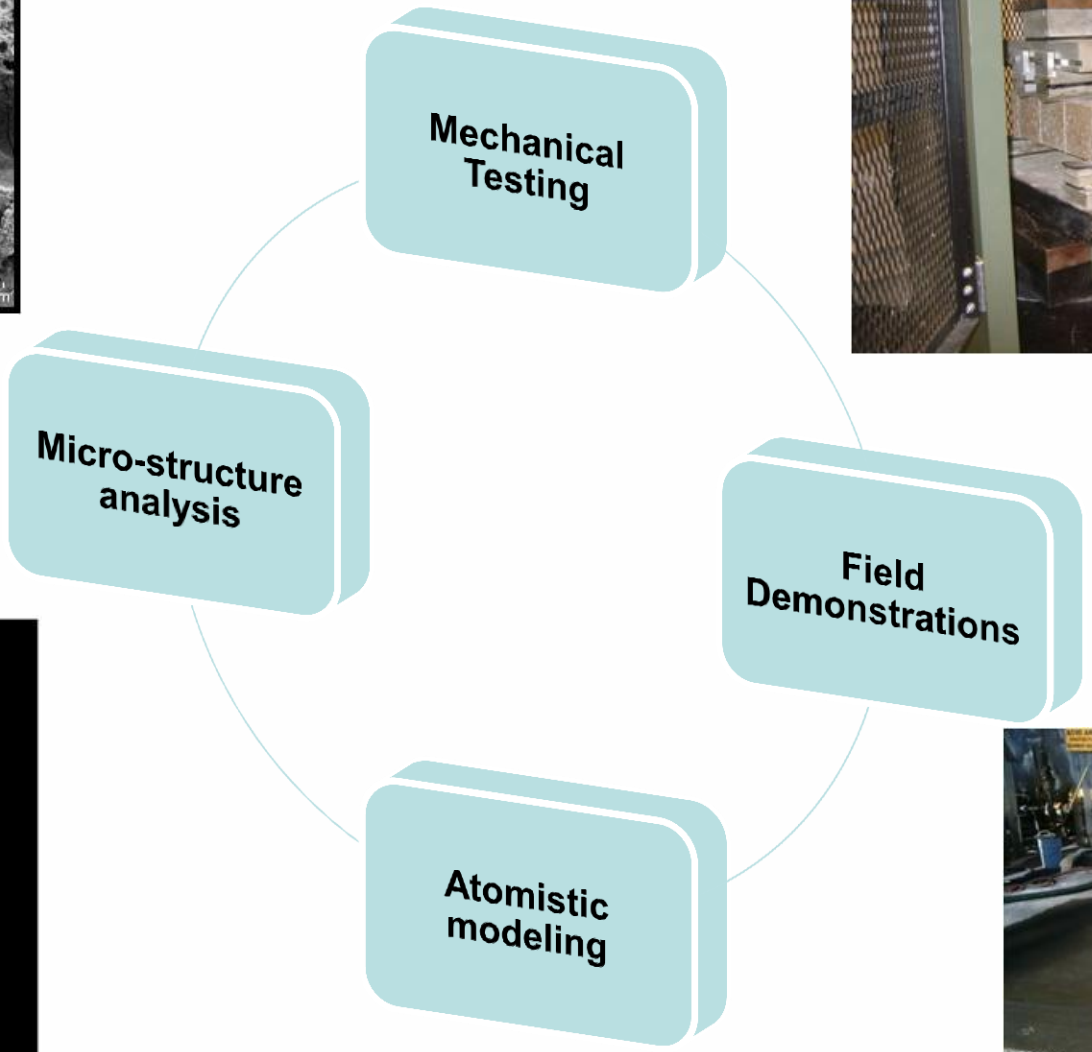
Geopolymer offer high mechanical strength, along with high corrosion resistance and resistance to elevated temperatures (up to 2800° F). Potentially a cost effective, low cost, locally available refractory material for low-pH high temperature biomass incinerators.



ASTM C 704- Abrasion Resistance of Refractory Materials

Multi-Disciplinary Integrated Approach for Accelerating Product Development and Validation



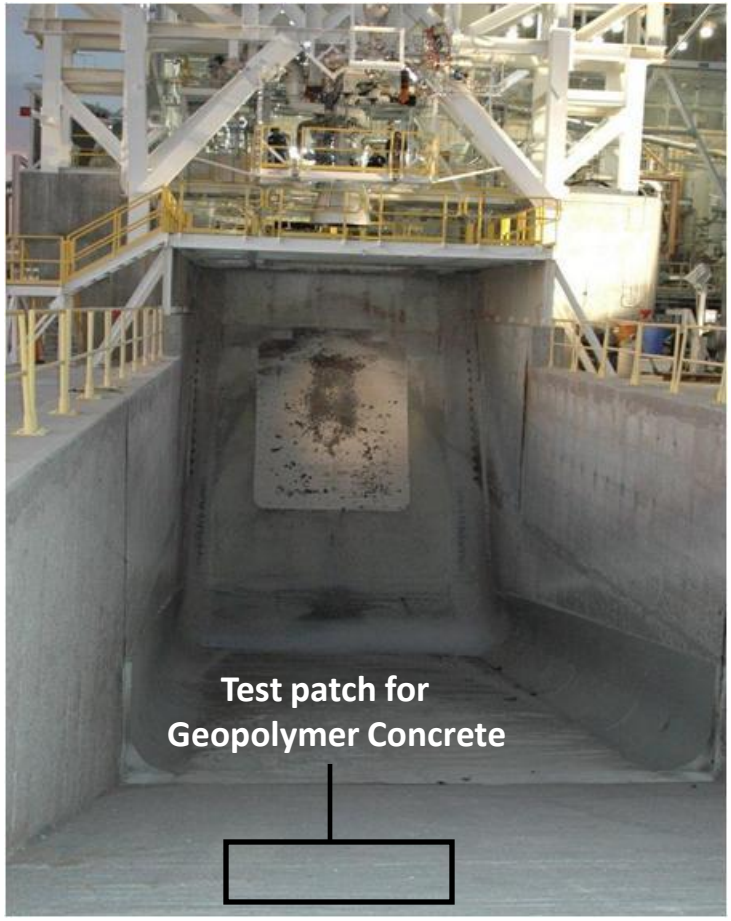


Pilot Project #1
Repair of an animal incinerator, Ruston, LA

Before Rehabilitation

After Rehabilitation using Geopolymer grout

Pilot Project #2
Installation of Test Patch in Test Cell E1
NASA Stennis, MS



Pilot Project #3
Installation of Acid Spill Pad (12 x 15 ft)
Clearwater Paper Corporation , AR

Relevant Publications & Patents

- Allouche E.N. and Montes, C. (2010). Geopolymer Mortar and Method. Non-provisional patent application submitted to the USPTO on December 20, 2010. USPTO Serial No. 12/972,722 / PCT/US11/65854.
- Allouche, E.N. and Diaz, E.I. (2011). Incinerator Fly Ash Geopolymer and Method. Provisional patent with the International Patent Office (Application Number 61/528,230).
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- Kupwade-Patil K. and Allouche E.N. (2011). Impact of Alkali Silica Reaction on Fly Ash based Geopolymer Concrete. Journal of Materials in Civil Engineering, ASCE.
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- Diaz, E., Allouche, E., Eklund, S., Joshi, A. and Kupwade K. (2011). Toxicity Mitigation and Solidification of Municipal Solid Waste Incinerator Fly Ash using Alkaline Activated Coal Ash. J. Waste Management.
- Vaidya, S. and Allouche E.N. (2011)**.** Strain Sensing of Carbon Fiber Reinforced Geopolymer Concrete**,** Materials and Structures, Vol. 44, No. 8, pp.1467-1475. *Springer*, U.K., August.
- Diaz E.I, Allouche, E.N. and Vaidya, S. (2011). Mechanical Properties of Fly Ash-Based Geopolymer Concrete. ACI Materials Journal, Vol. 108(3), pp. 300-306, May - June.
- Vaidya, S. and Allouche E.N. (2011). Experimental Evaluation of Electrical Conductivity of Carbon Fiber Reinforced Fly-Ash Based Geopolymer. J. Smart Structures and Systems, Vol. 7(1), pp. 1-14.
- Vaidya, S. and Allouche E.N. (2010). Electrokinetically Deposited Coating for Increasing the Service Life of Partially Deteriorated Concrete Sewers. J. of Constr. and Building Mat., Vol. 24, pp. 2164-2170.
- Montes, C. and Allouche, E.N. (2010). Evaluation of Geopolymer Mortar for the Rehabilitation of Buried Infrastructure. J*ournal of Structures & Infrastructure Engineering: Maintenance, Management, Life-cycle, Design & Performance*,

Future Work

- Follow-up research proposals were submitted to:
  - NASA-EPSCoR – (in collaboration with LSU and Southern)
  - DOE's Innovative Manufacturing Processes Program (focus on refractory products for biomass incinerators)
  - National Science Foundation
  - NASA's Cooperative Agreement Notice titled "Geopolymer Binders in Rocket Plume Environments at NASA Stennis Space Center"
  - National Security Technologies

- Additional demonstration projects are planned with:
  - NASA Stennis (Test Stand Es/C2)
  - Cleco Power
  - City of Los Angeles
  - National Security Technologies