“Promoting and advancing the development of healthy, durable, and sustainable shelter for Alaskans and other Circumpolar people.”
About Cold Climate Housing Research Center

Promoting and advancing the development of healthy, durable, and sustainable shelter for Alaskans and other circumpolar people.

Founded October 1, 1999
About Cold Climate Housing Research Center

- Identify issues critical to creating shelter and related infrastructure for Circumpolar people
- Develop research projects to address these issues and initiate solutions
- Promote our findings
- Establish a product testing, development and certification program
- Stimulate local business enterprises
- Expand partnerships within the circumpolar north
Concrete Jungle

Concrete is used extensively for:
- Pavement
- Buildings
- Roads / bridges
- Pipes
- Footings
...and much, much more

Three tons are produced for every person on the planet per year and demand is increasing.
Portland cement is a hydraulic cement, which means that water is an integral part of its chemical structure.

- Water makes portland cement easy to use.

- Portland cement’s water-based bonding is the root of its disadvantages.
Portland Cement

Limestone, Clay and Gypsum
(Minerals containing Calcium, Silicon, Aluminum and Iron)

Water

Requires a huge manufacturing plant

Portland Cement
Disadvantages of Portland Cement

- Water absorption and expansion
- Premature deterioration requiring repair
- Poor performance in salty environments
- Damaged by fire
- Substantial CO$_2$ emissions during manufacturing
- All imported to Alaska (presently from Korea)
Emissions from Portland Cement Manufacturing

Creating one ton of Portland cement:

• Produces nearly one ton of CO$_2$
• Produces about 3 kg of NOX, an air contaminant that contributes to ground-level smog
• Produces about 0.4 kg of PM$_{10}$ – particulate matter that is harmful when inhaled

Portland cement manufacturing accounts for 8%-12% of CO$_2$ emissions worldwide
Geopolymers
Novel to - and needed by - Alaska

- 80% less CO$_2$ emissions*
- 2 to 4 times stronger*
- More durable*
- More stable*
- Less permeable*
- Self-adherent
- Fire resistant to >1800°F
- Acid, base & salt resistant
- Blast & earthquake resistant

* Than ordinary portland cement
Geopolymers* – Discovered in the 1950s

**Alumina Silicate**
- Coal Fly Ash
- Mine Tailings
- Silt
- Loess
- etc.

**Alkali Activator**
- Sodium Hydroxide
- Sodium Silicate

**Water**

Requires only a simple batch plant

**Geopolymer Cement**

* aka Alkali-Activated Alumino-silicate Cement
Advantages of Geopolymers

• Eliminates the need for portland cement and enables a significant reduction in global CO$_2$ emissions as development occurs

• Uses waste materials as the primary feedstock (e.g. mine tailings, industrial chemical wastes, low level radioactive wastes)

• Reduces cost and pollution as waste materials do not need to be landfilled

• Increases the design life of infrastructure

• Opens up opportunities for process and product improvements that take advantage of geopolymers’ unique properties
# Material Comparison

<table>
<thead>
<tr>
<th><strong>Comparison of Typical Physical Characteristics</strong></th>
<th><strong>OPC</strong></th>
<th><strong>MPCs</strong></th>
<th><strong>Geopolymers</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive Strength in psi (Typical)</td>
<td>3,000 - 7,000</td>
<td>8,000 - 12,000</td>
<td>5,000 - 16,000</td>
</tr>
<tr>
<td>Bending Tensile Strength in psi</td>
<td>250 - 1,000</td>
<td>900 - 1700</td>
<td>300 - 2,900</td>
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<tr>
<td>pH Tolerance</td>
<td>6.5 to 14</td>
<td>3 to 11</td>
<td>3 to 14</td>
</tr>
<tr>
<td>Salt Tolerant (Continuous Exposure)</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Max. Structural Temperature</td>
<td>1,500°F</td>
<td>2,300°F</td>
<td>2,000 - 2,700°F</td>
</tr>
<tr>
<td>Curing Time (Demolding)</td>
<td>1 - 2 Days</td>
<td>10 min - 2 hrs</td>
<td>3 hr - 3 days</td>
</tr>
<tr>
<td>Curing Time (High Strength)</td>
<td>28 days</td>
<td>3 days</td>
<td>3 days</td>
</tr>
<tr>
<td>Curing Temperature Range</td>
<td>5°F - 420°F</td>
<td>8°F - 110°F</td>
<td>50°F - 200°F</td>
</tr>
<tr>
<td>Bonds To Itself</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Bonds To Reinforcement</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Shrinks upon drying</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion</td>
<td>0.000012</td>
<td>0.00000017</td>
<td>~0.000001</td>
</tr>
<tr>
<td>Absorbs Water</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Foamable</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

OPC is Ordinary Portland Cement  
MPCs are Magnesium Phosphate Cements  
Geopolymers are alkali activated aluminosilicates
Our Work

Research and testing of Geopolymers and Magnesium Phosphate Cements at Cold Climate Housing Research Center
Using Alaskan Waste Materials

- **Ash** is the residue that remains after coal is burned
  - **Fly Ash** is the by-product collected from the flue gases (think of it as cement)
  - **Bottom ash** is the heavier and coarser by-product (think of it as aggregate)
- Roughly **300 tons of ash per day** are produced in the Fairbanks area
Alaskan Fly Ash

Fly Ash

Fly ash is microscopic spheres comprised of many metal oxides, but is mostly silica (SiO$_2$) and some alumina (Al$_2$O$_3$).

Other components vary with percentages of less than 30% total.

Alaskan coal produces ash that contains much more calcium than most ash elsewhere. That makes using it for geopolymer cement different, but it works.
Alaskan Resources – Not Wastes

Mine Tailings - Benign

Alaskan mines, like Fort Knox and Pogo, produce benign waste that still must be contained and monitored. They are a liability.

These tailings are predominantly finely-milled quartz, the result of extensive and expensive grinding.

This material makes good fill for geopolymers and other cements and possibly an active component.

More than 200 million tons of finely milled tailings are available in the Fort Knox gold mine retention pond.
Alaskan Wastes – From Bad to Good

Mine Tailings - Hazardous

One purpose of geopolymer development is the encapsulation of hazardous, radioactive and contaminated materials within an impervious, high strength material.

Tailings from Alaskan mines, like Red Dog, can be used to make geopolymers that bind their toxic components into a stable material.

Why not USE tailings from Pebble Mine instead of fighting over how to waste them?

For making sea wall blocks?
Other Alaskan Materials

Many Alumino-silicates will work

- Kaolin clay
  - from coal mine gangue (material layered in soil above coal deposits)

- Glacial silt / wind-blown loess

- Other clays, zeolites and naturally occurring alumina-silicates

- These will be especially important for producing geopolymer cement in rural Alaskan villages
Usefulness and Problems Solved

Local Geopolymer Production Will

- Provide low-cost, superior quality cement
- Decrease local manufacturing costs
- Create local jobs
- Utilize waste fly ash & mine tailings
- Decrease Alaskan infrastructure costs
- Reduce economic & environmental costs of future development throughout Alaska

Globally Geopolymers Will

- Enable sustainable development
- Decrease rate of CO$_2$ release
- Conserve fuel
- Improve health and safety

Not a pretty sight
Feasible and Incrementally Scalable

Large Scale Applications

- Building construction
- Railroad ties
- Roads and bridges
- Retention walls
- Sea walls
- Hazardous waste containment

Bay bridge construction
Geopolymer Concrete Railroad Ties

ARR Replaces 50,000 Every Year
• Presently imported for $3M annually
• Can be made in Alaska
• Reduced costs (esp. shipping)
• Do not degrade like wood
• Non-polluting
• Creates jobs
• Uses materials that are otherwise waste products
• Encourages expansion of Alaska’s rail lines to Canada and over the Yukon
• Used in European and Australian track

A railroad tie aka “sleeper”
Small Applications and Products

Niche Market Applications

- Pre-cast building panels
- Bricks, blocks, pavers, tiles, shingles
- Pipes, culverts
- Refractory applications
- Fireproof insulation and wall panels
- Road and infrastructure repair
- Bridge reinforcement
- Protective coatings
- Adhesives
Small Applications and Products

Countertops and Pre-Casting

- Alaska has existing countertop and pre-cast manufacturers
- Products can be made in Alaska
- Fireproof and durable
- Uses materials that are otherwise wasted
- Creates jobs
- Reduces importation of similar goods
- Non-polluting

A cast cement sink & counter
New Applications and Products

Insulation and Wall Panels

- Fireproof
- Made in Alaska
- Uses materials that are otherwise wasted
- Creates jobs
- Reduces importation of similar goods
- Non-polluting
- Innovative processes and product designs will be possible which take advantage of geopolymers’ unique performance characteristics.
Valuable over short & long terms

Value Capturing

- Incrementally scalable with investment
- Niche products require little investment
  - Simple, short run pre-cast products
  - Custom products like countertops
- Process and product innovation can be done in Alaska, developing IP for large-scale manufacturing elsewhere
- Meeting infrastructure demands will require greater investment and yield long term value
Current Manufactures

- Geopolymer Institute
- Rocla
- Zeobond
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Questions?

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