AGS is a Technology Licensing Company specializing in the design and development of fly ash based geopolymer products solving problems for multiple industries including oil/gas well solutions.

**AGS line of products include:**

- Castable and pre-cast refractory concrete
- Castable and pre-cast corrosion resistant concrete
- Well cementing
- Proppants
Value Proposition

Well cementing

- Higher sulfate resistance compared with traditional cementation grouts.
- Lower shrinkage reducing potential cracking
- Enhanced bond to steel casing
- Setting time can be chemically “programmed” using proprietary additives developed using an advanced nanotechnology process.
- Water works as a carrier and not part of the chemical formulation

Proppants

- Lower cost compared with ceramics
- Increased conductivity compared to sand and resin coated sand
- Increased acid resistant to sulfates
- AGS Spherical-shaped proponents cause lower wear on expensive well equipment compared to sand or resin coated sand

Green Appeal - Environmentally and Economically Attractive
## Typical characteristics of AGS Geopolymer Concrete

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Standard</th>
<th>Typical Values/ Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mechanical Properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressive Strength*</td>
<td>C-39</td>
<td>80 MPa (11,600 psi)</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>C-78</td>
<td>7.4 MPa (1,073 psi)</td>
</tr>
<tr>
<td>Elastic Modulus</td>
<td>C-469</td>
<td>43 GPa (6,236 ksi)</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>C-469</td>
<td>0.11-0.2</td>
</tr>
<tr>
<td>Bond Strength</td>
<td>D-4541</td>
<td>9.6 MPa (1,400 psi)</td>
</tr>
<tr>
<td>Setting Time</td>
<td>C-403</td>
<td>25 - 600 minutes</td>
</tr>
<tr>
<td>Water Absorption</td>
<td>C-642</td>
<td>2%-8%</td>
</tr>
<tr>
<td>Density</td>
<td>C-642</td>
<td>1800 - 2350 kg/m³ (110 - 146 lb/ft³)</td>
</tr>
</tbody>
</table>

### Durability of Geopolymer Concrete

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Standard</th>
<th>Typical Values/ Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion Rate when subjected to one year of saltwater exposure</td>
<td>G-02</td>
<td>0.09 µA/cm²</td>
</tr>
<tr>
<td>Chloride Diffusion Coefficient</td>
<td>C-1556</td>
<td>1.45x10⁻¹² m²/s</td>
</tr>
<tr>
<td>% Expansion due to Alkali Silica Reaction (ASR)</td>
<td>C-1260</td>
<td>Min: 0.04 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max: 0.1%</td>
</tr>
<tr>
<td>Sulfate attack</td>
<td></td>
<td>Stable in 5 % solution of NaSO₄ &amp; MgSO₄</td>
</tr>
<tr>
<td>Corrosion Resistance</td>
<td>C-267</td>
<td>High level of resistance to a range of acids and salt solutions (Na₂SO₄, MgSO₄, NaCl, Sulphuric Acid, Hydrochloric Acid)</td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
<td>Thermal Stability up to 2500°F</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td></td>
<td>~0.2-0.3 W/m/K</td>
</tr>
</tbody>
</table>
AGS has developed a proprietary software to overcome the variability of the raw material chemical compositions and produce a material with constant quality.

With the use of AGS’s geopolymer software, geopolymer concrete can be designed for a wide range of compressive strengths and slumps as well as for different exposure conditions including freeze-thaw, corrosive environments and elevated temperature/fire by making use of our extensive fly ash database.
Geopolymerization Reaction

Dissolution of all components

Precipitation of aluminosilicate species

Polymerization of polymeric Si–O–Al–O bonds

Growth of 3D polymer chain from Si-O-Al-O bonds

Na or K Hydroxide + Sodium Silicate

Coal-fired power plant

Highly Alkaline Soln + Source Material

Geopolymerization Reaction

GPC (N-A-S-H) or (K-A-S-H)

X = Na or K

Si–O–Al–O bonds
High Temperature Resistance

• Resists shock effect of temperatures up to 4000°F, and continuous temperatures to 2800°F

• Outperforms products currently used on NASA launch pads, American Electric Power coal furnace, and Georgia Pacific acid tanks
High Corrosion Resistance

• Resists the action of most common industrial acids, such as sulfuric, nitric, etc.

• Cost-effective alternative to organic polymers
High Corrosion Resistance

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.
Waste to Energy Solutions

- Recycling of municipal waste ash into geopolymer products.

- Controlled low strength flowable fill manufactured from municipal waste ash to be used in beddings, encasements, closures for tanks and pipes, road crossings and general backfill for trenches and abutments.

- Recycling of landfilled fly and bottom ash.
AGS geopolymer proppants offers the following advantages:

- A cost effective alternative to ceramic proppants
- Low energy production process
- Manufactured 85% from fly ash, offering a green appeal
- Can be manufactured near shale plays, dramatically reducing transportation costs
- Offers greater performance than resin coated sand due to higher sphericity
- Lightweight
Comparison of manufacturing process with ceramic proppants

**CERAMIC PROPPANT**

1. Mining and crushing of raw materials
2. Mixing
3. Balling
4. Ball drying

**GEOPOLYMER PROPPANT**

1. Use of fly ash “as is”
2. Mixing and balling combined
3. Ball drying, low temperature curing
4. Densification*

* Densification is a low energy proprietary process to enhance the quality of geopolymer proppants.
Comparison of manufacturing process with ceramic proppants

CERAMIC PROPPANT

- Screening
- Sintering*
- Cooling
- Classification screening

GEOPOLYMER PROPPANT

- Classification screening
- Inspection and warehousing
- Inspection and warehousing

* The high energy sintering process is not required for fly ash geopolymer proppants.
<table>
<thead>
<tr>
<th>Property</th>
<th>API recommended</th>
<th>Typical/Competitor</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size distribution</td>
<td>Mesh 8/12, 10/20, 20/40, 70/140.</td>
<td>Mesh 20/40 or 40/70.</td>
<td>Mesh 20/40 or 40/70.</td>
</tr>
<tr>
<td>Sphericity and roundness</td>
<td>0.6 for both</td>
<td>0.9, 0.8</td>
<td>0.9, 0.8</td>
</tr>
<tr>
<td>Crush resistance</td>
<td>Size / Max fines by weight at compressive stress between 4000-6000 psi.</td>
<td>Max fines by wt. @5000psi 0.5% @7500 psi 2.0%</td>
<td>Max fines by wt. @5000psi 25%</td>
</tr>
<tr>
<td></td>
<td>6-12 mesh / 20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16-30 mesh / 14%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20-40 mesh / 14%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-50 mesh / 10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>40-70 mesh / 6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid solubility</td>
<td>&lt;7% solubility in a solution of 12 parts HCl-4 parts HF</td>
<td>4.8% solubility in 12/3 HCl/HF</td>
<td>6.4% solubility in 12/4 HCl/HF</td>
</tr>
<tr>
<td>Turbidity</td>
<td>N/A</td>
<td>&lt; 250 NTU</td>
<td>30 NTU</td>
</tr>
<tr>
<td>Bulk Density</td>
<td>Not specified</td>
<td>87-125 pcf</td>
<td>84 pcf</td>
</tr>
<tr>
<td>Apparent Specific Gravity</td>
<td>Not specified</td>
<td>2.5-3.5</td>
<td>1.34</td>
</tr>
<tr>
<td>Conductivity</td>
<td>Not specified</td>
<td>Depending on closure stress.</td>
<td>Not conducted yet</td>
</tr>
</tbody>
</table>
Geopolymer Well Cementing for ‘Tight’ Oil & Gas Wells

- The main problem associated with geopolymer underground applications is the control of their setting under high temperature and pressure.

- AGS well cement is the result of combining geopolymer technology and nano-technology.

- Capable of highly controlled rheological behavior across multiple pressure and temperature zones as a function of time.

Binder granular coated with ‘delay-action’ nano-particles.
Geopolymer Well Cementing for ‘Tight’ Oil & Gas Wells

- AGS nanoparticle treated geopolymer (DH TR + 6% ADD) has a thixotropic behavior even at 50 C (122 F), compared to traditional geopolymer formulations (DH and DH + 6% ADD), which start setting immediately.
- AGS geopolymer starts setting approximately 50 minutes after exposed to temperature, and finishes setting at approximately 2 hours, giving time for adequate placing.
- DH + 2% Ret shows that commonly used retarders prevent the setting of geopolymer under this conditions.
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