Geopolymer concrete can be the solution for sustainable infrastructure

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Outlines

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- Previous work
- Materials
- Marketing research
- Marketing strategy
- Conclusions
- Acknowledgement
Due to the global concern about CO$_2$ emissions nowadays, Portland cement is responsible for (7-10)% of total CO$_2$ [Chen et al; 2010]. Alkali activated geopolymer cement is one potential alternative to Portland cement.

Heidrich and et al, 2010
**Activating solutions**

- The silica fume based activating solution was a mixture of sodium hydroxide flakes dissolved in water, along with silica fume powder. Following the addition of silica fume powder, the entire mixture was stirred for two minutes. The mixing of silica fume with sodium hydroxide and water was an exothermic process (in excess of 80 °C [176 °F])

- The mixing procedure described above is the same as described in Assi et al; 2016 (Assi et al 2016).
Previous work (FSA) (heat-cured)
Previous work (FSA)

- Compressive strength (MPa)
- External heat (C)
- Sodium hydroxide/binder (%)

Graphs showing:
- 0 Portland Cement (III)
- 5% Portland Cement (III)
- 10% Portland Cement (III)
- 15% Portland Cement (III)

Age (days) vs. Compressive strength (MPa)

Compressive strength (psi)

Sodium hydroxide/binder (%)

Hydration products Microcracks
Calculating the actual cost of geopolymer and Portland cement concrete

Table  Mixture proportions of FSA geopolymer concrete mixture [5]

<table>
<thead>
<tr>
<th>Concrete type</th>
<th>Fly ash (type F), kg/m³ (lb/ft³)</th>
<th>Water, kg/m³ (lb/ft³)</th>
<th>w/b ratio</th>
<th>Sodium hydroxide, kg/m³ (lb/ft³)</th>
<th>Silica fume, kg/m³ (lb/ft³)</th>
<th>Compressive strength, MPa (psi) SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix 1: silica fume based activating solution</td>
<td>474 (29.6)</td>
<td>163 (10.2)</td>
<td>0.28</td>
<td>61.6 (3.81)</td>
<td>46.2 (2.91)</td>
<td>106 (15,400) 4.96 (720)</td>
</tr>
</tbody>
</table>

Table Raw materials price

<table>
<thead>
<tr>
<th>Raw materials</th>
<th>$/metric ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Type I,</td>
<td>106</td>
</tr>
<tr>
<td>Silica fume</td>
<td>640</td>
</tr>
<tr>
<td>Fly ash (type F)</td>
<td>35.0</td>
</tr>
<tr>
<td>Sodium hydroxide (50 %)</td>
<td>580</td>
</tr>
</tbody>
</table>
Calculating the actual cost of geopolymer and Portland cement concrete

Figure Cost of geopolymer and Portland cement concrete
Calculating the actual cost of geopolymer and Portland cement concrete

Figure Fuel (Thermal energy) usage

- Portland cement: 2.35
- Sodium hydroxide: 1.26
- Curing: 0.05
- Heat of activating solution: 0.1

Portland cement
Geopolymer cement
Required energy (GJ/m³)
Geopolymer properties

- High compressive strength
- Low permeability leading to enhance durability performance.
- High early age strength
- High performance in high temperatures
- Resistance against acid
- Resistance against sulfate attacks
Marketing research

Please rate your agreement with each statement below. If I were looking for information about new cement/concrete products, I would go to __________ for information.
Marketing research

Based on your perception, rate the most critical barriers to switching to geopolymer concrete/cement?

<table>
<thead>
<tr>
<th>Field</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Purchase Cost</td>
<td>60</td>
</tr>
<tr>
<td>Lack of Confidence in the Concrete/Cement</td>
<td>50</td>
</tr>
<tr>
<td>Availability</td>
<td>70</td>
</tr>
<tr>
<td>Uncertainty of Durability</td>
<td>70</td>
</tr>
<tr>
<td>Uncertainty of Fire resistance</td>
<td>50</td>
</tr>
<tr>
<td>Uncertainty of Compressive Strength</td>
<td>70</td>
</tr>
<tr>
<td>Uncertainty of Early Age Strength</td>
<td>70</td>
</tr>
<tr>
<td>Uncertainty of Resistance against Acid Attack</td>
<td>40</td>
</tr>
<tr>
<td>Uncertainty of Resistance against Sulfate Attack</td>
<td>70</td>
</tr>
<tr>
<td>Contracts with existing suppliers</td>
<td>40</td>
</tr>
<tr>
<td>Regulatory Compliance</td>
<td>70</td>
</tr>
</tbody>
</table>
Marketing research

Please rate your familiarity with each of the following:

- Not familiar at all
- Slightly familiar
- Moderately familiar
- Very familiar
- Extremely familiar

Legend:
- Red: Geopolymer concrete
- Blue: High volume of fly ash (HVFA) concrete
- Purple: Sustainable concrete
Compared to other available concrete/cement alternatives, rate your perception of the properties of geopolymer cement/concrete.
Figure Global Portland cement market from year 1998 to 2020
Marketing strategy

2. Product

**Product Properties:**
- High compressive strength
- Low permeability leading to enhance durability performance.
- High early age strength
- High performance in high temperatures
- Resistance against acid
- Resistance against sulfate attacks

**Product Benefits:**
- Utilization of waste materials such as fly ash and slag
- 40% Reduction of thermal energy and CO$_2$ emissions
- Reduction in water usage and labor cost as it does not require water for extended curing
- A different perspective on concrete (not only having promising properties but also helping future generation)
# Marketing strategy

## 2. Product

<table>
<thead>
<tr>
<th>Properties</th>
<th>FSA concrete</th>
<th>Geopolymer concrete</th>
<th>Portland cement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strength gain</strong></td>
<td>Within 4 hrs, in presence of heat</td>
<td>Within 4 hrs, in presence of heat</td>
<td>Three days, 72 hrs</td>
</tr>
<tr>
<td><strong>Availability in the market</strong></td>
<td>Not</td>
<td>Not</td>
<td>Available</td>
</tr>
<tr>
<td><strong>Workability</strong></td>
<td>Good workability</td>
<td>Moderate</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td>Competitive with Portland</td>
<td>High</td>
<td>The lowest</td>
</tr>
<tr>
<td><strong>Energy consumption</strong></td>
<td>40% reduction</td>
<td>40% reduction</td>
<td>0 reduction</td>
</tr>
<tr>
<td><strong>Waste material utilization</strong></td>
<td>100% utilization</td>
<td>100% utilization</td>
<td>0-30% utilization</td>
</tr>
<tr>
<td><strong>External heat presence</strong></td>
<td>Based on the requirement, (with/o) external heat</td>
<td>Mostly needs external heat</td>
<td>Based on the requirement, (with/o) external heat</td>
</tr>
<tr>
<td><strong>Acid attack resistance</strong></td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td><strong>Fire resistance</strong></td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
### Table SWOT analysis

**Strength**

- Suitable for multiple applications including sidewalks, roofs, precast walls and prestressed elements
- Provides a solution for fly ash, which is produced by coal-generated power plants and has a negative environmental impact when stored
- Reduces energy consumption leads to low CO$_2$ emissions by 40% relative to Portland cement
- Does not require external heat
- Superior durability and compressive strength relative to Portland cement

**Weakness**

- 20% production cost premium relative to Portland cement
- Lack of market knowledge regarding geopolymer concrete as an alternative to Portland cement

**Opportunities**

- Increasing global pressure and regulatory actions to reduce CO$_2$ emissions and use sustainable products
- High coal combustion producers such as China, the United States, and Russia are under pressure to find solutions to utilize waste materials (e.g., fly ash)
- Growing emphasis on sustainable construction/buildings (e.g., US Green Building Council – LEED)

**Threats**

- Fluctuation in raw material prices, particularly sodium hydroxide
- Increasing demand for waste materials used as a raw material in the proposed mixture (e.g., fly ash)
- Almost ubiquitous use of Portland cement
Marketing strategy

3. Pricing

- The superior properties
- Improved durability
- Reduction of CO₂ emissions
- Reduction of water usage
- Use of environmentally-harmful waste products in the production process
Conclusions

• The study shows that geopolymer concrete could be used in infrastructure applications due to its superior mechanical and chemical properties once a coherent marketing plan is conducted.
• The marketing plan showed that geopolymer concrete could be a profitable business to be initiated specifically in the United States.
• Communication campaigns suggest that raising the awareness about CO2 emission issues, and informing them about how much the green cement (geopolymer cement) can be an ideal solution, would help to enlarge the success of the green cement business.
• Based on the raw material availability, fastest-growing economies, and the traffic highway destinations five cities (Charlotte, Cleveland, Milwaukee, Chicago, and Cincinnati) are suggested to initiate the geopolymer concrete business.
• One of the best means to advertise is the concrete conventions such as ACI and ASCE conventions because many contractors and concrete experts are gathered there.
Acknowledgement

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Thank you