Research on the Utilization of Coal Ash for Geopolymers at the University of Indonesia
What is geopolimer?

Figure 1 Molecular structure model for geopolimer [J. Davidovits, J. Thermal Anal., 37 (1991) 1633–1656.]
Geopolymer precursors

- Fly ash
- Blast furnace slags
- Dehydroxylated kaolin
- Red mud
- etc
Figure 2 Dissolution & polycondensation of aluminosilicate geopolymers

\[
(Si_2O_5Al_2O_2)n + nH_2O \xrightarrow{\text{KOH, NaOH}} n(OH)_3 - Si - O - Al - (OH)_3 \\
\text{(OH)}_2
\]

\[
\xrightarrow{\text{(Na,K)}} \quad \text{O} \quad \text{O} \quad \text{O} \\
\text{(OH)}_2 \quad \text{O} \quad \text{O} \quad \text{O} \\
\text{St} - O - Al - O - St - (OH)_3 \\
\quad \text{NaOH, KOH}
\]

\[
\text{St} - O - Al - O - St - O - St - O + 6H_2O
\]

Geopolymer properties

- Ceramic properties:
  - high hardness,
  - High strength, and
  - heat resistance

- Plastic properties:
  - low temperature processing and formability
  - Near net shape
Figure 3. General applications of aluminosilicate-based inorganic polymers
McCormick, P.G., Inorganic Polymer, a new material for the new millennium, unpublished paper, University of Western Australia, 2000
GEOPOLYMER

**APPLICATION**

- **Flyash**
  - Rapid setting cement/binder
  - Aggressive Environment
  - Heat/fire Resistance
  - Waste Containment
  - Building Materials
  - Composites

- **Bottom Ash, silica fume, waste aggregates**

- **Kaolin**
  - Micro/molecular structure
  - Curing Behaviour
  - Thermal Analysis
  - Mechanical properties

- **Synthetic**

**STRUCTURE PROPERTIES**
Geopolymers as rapid setting cements

(Hibah Bersaing 2009, 2010 & RUUI 2010)
Figure 5 Compressive strength of fly ash-based geopolymer paste as a function of curing time. Curing temperature 60°C and RT

Figure 6 Compressive strength of kaolin based–geopolymer paste as a function of curing time. Curing temperature 60°C and RT
Figure 7 Compressive strength of fly ash and kaolin–based geopolymer paste as a function of curing time (hours). Curing temperature 60°C
In situ DSC

Figure 8  Heat flow of geopolymer paste at 50° C during 24 hours.
Increasing the curing temperature reduce the curing time to achieve the same target strength. At 90°C, fly ash geopolymers achieve compressive strength of ~40 MPa at 4 hours and ~46 MPa at 8 hours. On the other hand, a compressive strength of ~27 MPa seems to be the maximum strength of kaolin geopolymers and can be achieve in only 2 hours curing at 90°C.
Geopolymers in aggressive environments

Hibah Strategis Nasional, 2009–2010
Figure 9 Comparison of the behavior of fly ash, dehydroxylated kaolin and Portland cement concretes upon seawater immersion.
Figure 10 Comparison of the behavior of fly ash, dehydroxylated kaolin and Portland cement concretes upon distilled water immersion.
<table>
<thead>
<tr>
<th>Concrete types</th>
<th>Medium</th>
<th>Day-</th>
<th>Pourbaix Diagram plot</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Portland cement</td>
<td>Distilled water</td>
<td>-0.529 V; pH 7.2</td>
<td>-0.543 V; pH 7.2</td>
</tr>
<tr>
<td></td>
<td>ASTM seawater</td>
<td>-0.205 V; pH 8.2</td>
<td>-0.319; pH 8.2</td>
</tr>
<tr>
<td>Fly ash geopolymer</td>
<td>Distilled water</td>
<td>-0.293 V; pH 7.2</td>
<td>-0.183 V; pH 10</td>
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<tr>
<td></td>
<td>ASTM seawater</td>
<td>-0.427 V; pH 8.2</td>
<td>-0.327 V; pH 9</td>
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<tr>
<td>Kaolin geopolymer</td>
<td>Distilled water</td>
<td>-0.299 V; pH 7.2</td>
<td>-0.243 V; pH 10</td>
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<tr>
<td></td>
<td>ASTM seawater</td>
<td>-0.531 V; pH 8.2</td>
<td>-0.523; pH 10.9</td>
</tr>
</tbody>
</table>

Table 1 Comparison of corrosion behaviour of steels reinforcing PC–, fly ash geopolymer– and kaolin geopolymer– concretes.
Geopolymers as building materials

- fly ash
- Kaolin
- Blast furnace slags
- Bottom ash
- Waste aggregates
- Silica fume
In general, the mechanical properties (i.e. compressive and flexural strength) of geopolymer concretes are comparable with the ordinary Portland cement (OPC) concretes. Using the same mix design for conventional concrete, geopolymer concretes achieve the target strength in 3 days while the OPC can reach the target strength in 28 days.
Mixing
casting
Compression test
Data tersebut dibandingkan dengan tahanan lentur dari balok konvensional biasa yaitu \(0.7\sqrt{fc'}\) yaitu 4,427 Mpa
microstructures