Development Of Low Cost Geopolymer From Calcined Sedimentary Clay

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Introduction
Objective:
Developed geopolymer from the low cost and world wide available raw materials
Geopolymer precursor:

- Kaolinite clay
- Tablewares
- Sanitarywares
- Tiles
- Refractory
- Cement
- Slag
- Fly ash

Price is increased

Their supply is limited
K$_2$O$\cdot$Al$_2$O$_3$$\cdot$6SiO$_2$ (Feldspar)

Hydrolysis

Al$_2$O$_3$$\cdot$6SiO$_2$$\cdot$H$_2$O

Desilication

[Pyrophyllite]

Al$_2$O$_3$$\cdot$4SiO$_2$$\cdot$H$_2$O

Desilication

Al$_2$O$_3$$\cdot$2SiO$_2$$\cdot$2H$_2$O

Copy from document of Dr. Veeryuth Lorprayoon
Sedimentary clay (SC) is a clay mineral, which was transformed from primary clay by geological process.
Primary Clay:
Kaolinite Clay

Secondary or Sedimentary Clay:
Ball clay, Red clay, Plastic clay
0.9 CHF/Piece
Price of Dan Kwian Clay
≈ 27 CHF/ton

Price of Kaolinite Clay
≈ 425 CHF/ton**

Experimental procedural
อำเภอparsersociety
อำเภอโคกชัย
Parameters:

- Calcined time
- $\text{Na}_2\text{SiO}_3:\text{NaOH}$ ratios
DK
Drying
Disk mill
Pass 100 mesh
...XRD, XRF
Calcined 600 °C, 1, 2, 5 hrs.
Calcined 600 °C, 1, 2, 5 hrs.

NaOH, 8 M

Na$_2$SiO$_3$

Mixed
Na$_2$SiO$_3$:NaOH=0.5, 1, 1.5

Stored of 24 hours

DK

Drying

Disk mill

Pass 100 mesh

...→ XRD, XRF

Calcined 600 °C, 1, 2, 5 hrs.
Calcined 600 °C, 1, 2, 5 hrs.

NaOH, 8 M

Na₂SiO₃

Mixed

Na₂SiO₃:NaOH=0.5, 1, 1.5

Stored of 24 hours

Mixed

Powder:Liquid = 2.0

DK

Drying

Disk mill

Pass 100 mesh

... XRD, XRF

Calcined 600 °C, 1, 2, 5 hrs.
Calcined at 600 °C, 1, 2, 5 hrs.

NaOH, 8 M

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Na₂SiO₃:NaOH=0.5, 1, 1.5

 Stored for 24 hours

Mixed
Powder:Liquid = 2.0

Forming ASTM C109

DK

Drying

Disk mill

Pass 100 mesh

XRD, XRF

Calcined at 600 °C, 1, 2, 5 hrs.
NaOH, 8 M

Mixed
$\text{Na}_2\text{SiO}_3:\text{NaOH}=0.5, 1, 1.5$

Stored for 24 hours

Mixed
Powder:Liquid = 2.0

Forming
ASTMC109

Cured at 60 °C, 7 days

Calcined 600 °C, 1, 2, 5 hrs.

Drying

Disk mill

Pass 100 mesh
Calcined at 600 °C, 1, 2, 5 hrs.

NaOH, 8 M

Mixed
Na₂SiO₃:NaOH=0.5, 1, 1.5

Stored for 24 hours

Mixed
Powder:Liquid = 2.0

Cured at 60 °C, 7 days

Forming
ASTMC109

Test

Drying

Disk mill

Pass 100 mesh

DK

XRD, XRF
Q = Quartz
K = Kaolinite
<table>
<thead>
<tr>
<th>Compositions</th>
<th>Weight%</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO$_2$</td>
<td>72.95</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td>18.76</td>
</tr>
<tr>
<td>K$_2$O</td>
<td>1.02</td>
</tr>
<tr>
<td>CaO</td>
<td>0.38</td>
</tr>
<tr>
<td>MgO</td>
<td>1.19</td>
</tr>
<tr>
<td>TiO$_2$</td>
<td>0.84</td>
</tr>
<tr>
<td>Fe$_2$O$_3$</td>
<td>4.72</td>
</tr>
<tr>
<td>Etc.</td>
<td>0.14</td>
</tr>
<tr>
<td>Mineral</td>
<td>Content (wt%)</td>
</tr>
<tr>
<td>------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Kaolinite</td>
<td>42.3</td>
</tr>
<tr>
<td>Quartz</td>
<td>45.7</td>
</tr>
<tr>
<td>Feldspar</td>
<td>5.6</td>
</tr>
</tbody>
</table>

Approximated by the rational mineralogical analysis method
• DK is a useful raw material for a synthesis of the sustainable geopolymer

• It is comprised of the geopolymer precursor (kaolinite) and the filler (quartz and feldspar).
Effect of calcined time
• The high reactivity powder has a short period of setting time.

• The calcination is a process to manufacture reactive meta-kaolin.

• Excessive calcination temperature and/or period of the calcination time reduce reactivity of meta-kaolin.
Too short  Reactive meta kaolin  Low reactivity meta kaolin

Too short  Optimum  Too long
Effect of $\text{Na}_2\text{SiO}_3$:NaOH
Minimum requirement of OPC = 19 MPa
[ASTM C150/C150M]
• Role of NaOH and Na$_2$SiO$_3$ in geopolymerization process is the **dissolvent** and the **binder**, respectively.

• Although Na$_2$SiO$_3$ is required but it **inhibit** the geopolymerization process at the high Na$_2$SiO$_3$/NaOH ratio.
• Na$_2$SiO$_3$/NaOH ratio of 1.0 contains insufficient amount of both dissolvent and binder

• Geopolymerization process lacks Al and Si ion to form geopolymer gel, and lacks binder for condensation process
• Since NaOH is cheaper than Na$_2$SiO$_3$

• Na$_2$SiO$_3$/NaOH ratio of 0.5 benefits not only in term of engineering but also economic points of view.

• High strength geopolymer could be synthesized from a low cost raw material and a low cost alkali activator solution.
Conclusions
• Low cost and sustainable geopolymer is developed by using DKC as a precursor
• Strength of DKC-geopolymer is higher than that of the minimum requirement of the OPC
• Sufficient calcination time is required for obtaining the high reactivity calcined precursor
• Strength of geopolymer reduces with increasing the ratio of $\text{Na}_2\text{SiO}_3/\text{NaOH}$
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