An assessment of drying shrinkage in metakaolin-based geopolymers

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Problem: Cracking of Geopolymers

Investigation why cracking occurs

Conclusions
Problem: Cracking of Geopolymers

Geopolymers cured over a long time at room temperature, without cover
Experiments

metakaolin, Na$_2$SiO$_3$ + NaOH solution was mixed
1 day cured in sealed bags at RT and removed
further curing in sealed bags for 56 days
molar ratio was altered

- Al:Si:Na:H$_2$O 1:2:1:x x = 7.5 to 10.5
- Al:Si:Na:H$_2$O 1:x:1:8 x = 1.6 to 2.4
- Al:Si:Na:H$_2$O 1:2:x:8 x = 0.75 to 1.3
- Al:Si:x:H$_2$O 1:2:1:8 x = Na/K
Influence of $\text{H}_2\text{O}$ on cracking

Dilatometer results

![Graph showing dilatometer results](image)
Influence of $\text{H}_2\text{O}$ on cracking

Shrinkage measured using an extensometer

Graph showing the relationship between shrinkage and sample mass loss due to water evaporation for different water contents. The graph includes lines for 7.5 water, 8.5 water, 9.5 water, and 10.5 water.
Influence of H$_2$O on cracking

**Flexural strength: 3 point bending test**

![Graph showing flexural strength and sample mass loss due to water evaporation over varying water contents](image)
Influence of $H_2O$ on cracking

Shrinkage of Geopolymers

![Graph showing the relationship between water ratio and sample mass loss due to water evaporation. The graph includes three linear regression lines with $R^2$ values of 0.9287, 0.9865, and 0.9824. The x-axis represents the water ratio in mol, and the y-axis represents the sample mass loss due to water evaporation in %. The graph also includes markers indicating flexural strength and extensometer data.]
Influence of Si on cracking

Onset point of shrinkage measured using extensometer

![Graph showing the relationship between sample mass loss due to water evaporation and ratio Si:Al. The graph includes data points and a line of best fit with an R squared value of 0.9758.]

- Max. sample mass loss [%]
- Ratio Si:Al [mol]
- Sample mass loss due to water evaporation [%]
Influence of Si on cracking

Shrinkage during heating determined by dilatometry

![Graph showing shrinkage during heating for different Si:Al ratios](image)
Influence of Si on cracking


a) Si/Al 1.15
b) Si/Al 1.40
c) Si/Al 1.65
d) Si/Al 1.90
Influence of Na on cracking

Onset point of shrinkage measured using extensometer

![Graph showing the relationship between sample mass loss and Na:Al ratio. The graph indicates a linear trend with a correlation coefficient of R²=0.9652.](image)
Influence of Na/K and Si ratio on cracking

Onset point of shrinkage measured using extensometer
Influence of Na/K and Si ratio on cracking

Shrinkage during heating determined by dilatometry
Influence of Na/K and Si ratio on cracking

Comparing Na and K

<table>
<thead>
<tr>
<th></th>
<th>Na⁺</th>
<th>K⁺</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius, Å</td>
<td>0.97</td>
<td>1.33</td>
</tr>
<tr>
<td>charge density [Z/r]</td>
<td>1</td>
<td>0.75</td>
</tr>
<tr>
<td>$\Delta H_{\text{hyd}}^\circ$/kJmol⁻¹</td>
<td>-406</td>
<td>-322</td>
</tr>
</tbody>
</table>

Na has high charge density, means it remains hydrated during geopolymerisation

K has smaller hydration sphere compared to Na and water bond weaker
Conclusion
Results to date

Influence of water saturation after cation has lost hydration sphere

Influence of inert filler

• mechanical and flow properties

Influence of inert filler size

Influence of active filler e.g. MgO, CaO and OPC

• mechanical and flow properties
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