The Economics, Performance, and Sustainability of Internally Cured Concrete, Part 1

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Content

- Background
- Motivation for research
- Studies and results
  - Fiber characterization
  - Internal curing capacity
- Conclusions
- Q&A

Background

- Not only HPC but also hot weather concrete that requires special care for placing and finishing.
- Cement-based plaster also subject to water loss.
- Cracking is the most frequent cause of complaint.

Background

- Hot weather predominates in many regions.
Why pulps?

- Natural fiber is "green."
  - Contributes to the sustainability of concrete
- Pulp has several additional advantages:
  - May substantially reduce autogenous shrinkage
  - Provides additional resistance to shrinkage-induced cracking
  - Provides post-cracking ductility
  - Is found all over the world (accessible and economical)

Motivation for research

Mohr et al. (2005):
- TMP softwood fiber was effective at reducing autogenous shrinkage.
- Kraft fiber (k=1) was less effective than TMP fiber (k=3.3).

Mezencevova et al. (2012):
- Compared the internal curing efficiency of untreated TMP softwood to chemical-treated TMP softwood fibers
- Lacked information about fiber morphology

Prior efforts have focused on softwood fibers. Hardwood fibers examined here have been relatively unexplored for internal curing.

Motivation for research

Water in wet pulp

Wet pulp contains both free and bound water.

Free water in cell cavity (lumen)

Motivation for research

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Fiber characterization

As received fiber

Physical properties
- Fiber quality analysis (by using FQA)
  - Length
  - Coarseness
  - Percent fines
- Fiber morphology (by using SEM)
  - Cross-sectional dimensions (by image analysis)

Chemical properties
- Chemical compositions
  - Lignin content
  - Cellulose-to-hemicellulose ratio (by using TGA)
- Absorption capacity
  (by using calorimeter)
- Hard-to-remove water content
  (by using TGA)

Fiber quality analysis (by using FQA)
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Absorption capacity
(by using calorimeter)

Hard-to-remove water content
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Fiber characterization

Fiber morphology: fiber diameter, lumen diameter, cell wall thickness

Data were determined based on a statistical analysis of 350 cross-sectional fiber images.

Absorption capacity, \( k \): the amount of water absorbed by dry fiber

Heat released from cement pastes

\( \text{TAM air isothermal calorimeter} \)

Fiber properties

<table>
<thead>
<tr>
<th>Fiber Properties</th>
<th>USF</th>
<th>BSF</th>
<th>UKF</th>
<th>BKF</th>
<th>SCF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorption capacity, ( k )</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Cellulose-to-hemicellulose ratio</td>
<td>3.99</td>
<td>5.89</td>
<td>3.01</td>
<td>4.49</td>
<td>1.05</td>
</tr>
<tr>
<td>HR water content (g/g dry fiber)</td>
<td>1.44±0.11</td>
<td>1.45±0.01</td>
<td>1.30±0.02</td>
<td>1.37±0.09</td>
<td>1.76±0.06</td>
</tr>
<tr>
<td>Cell wall thickness (µm)</td>
<td>3.924</td>
<td>3.904</td>
<td>3.631</td>
<td>3.728</td>
<td>4.372</td>
</tr>
</tbody>
</table>

High cellulose content was found in full chemically-treated fibers.

No clear relationship was obtained between \( k \) and HR water content.

A thicker cell wall corresponds to higher amount of HR water.
Properties of fiber-cement composites

The cellulose-to-hemicellulose ratio did not significantly affect the internal curing capacity of the fibers.

The higher the HR water content, the better internal curing capacity.

- Fiber bundling related to the method of fiber processing is found in SCF.
- SCF could not be adequately dispersed.

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Conclusions

- The internal curing efficiency of pulp fiber relates more strongly to their physical morphology than to their variations in chemical composition.
- HR water content could be a meaningful parameter for the assessment of pulp fibers as internal curing agents.
- HR water content, appears to be related to increasing cell wall thickness.

Conclusions

- Soda fibers with higher HR water content exhibited better autogenous mitigating efficiency.
- For hardwood pulp fibers, a slower moisture release rate appears to be more favorable for internal curing.
- Confirming observations in other research, the dispersability of the internal curing agent was found to affect the fiber capacity for mitigating autogenous shrinkage.

Conclusions

- Internal curing mechanism in pulp fibers. Unlike LWA and SAPs, the slower rate of water release could be more favorable.

Future research plan

- NMR/ MRI preliminary results

Acknowledgements

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