Flowable Slurry Made With Class C Fly Ash and Paper Industry Fibrous Residuals

by

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Pulp and Paper Mill Wastewater Treatment Residuals

• Solid residue removed from mill wastewater before the water is discharged or reused.
• Removed via a two-step (primary/gravity and secondary/biological).
• Usually, dewatered before disposal or beneficial use.
Objectives

• Establish technical and performance benefits of using pulp and paper mill residual solids in flowable slurry.

• Improve setting & hardening and long-term strength of flowable slurry.

• Establish optimum mixture proportions for flowable slurry containing residual solids.
Characterization of the Residuals

• Residual solids from two sources were selected.
  – WR: Screening rejects from a pulp mill
  – C1: Waste-water treatment residual from a pulp/paper mill

• Physical and chemical properties determined.
As-received fibrous residual WR
As-received fibrous residual C1
No Pretreatment of Residuals

• The fibrous residuals were used as-received and not “re-pulped.”
Flowable Slurry Laboratory Mixtures

Mixture proportions were established through preliminary mixing and testing of coal ash slurry mixtures containing various amounts of:

- Cement
- Class C fly ash
- Water
- Fibrous residuals
Water, fibrous residual C1, cement, and fly ash in the mixer
Casting cylindrical specimens for compressive strength
## Mixture Proportions and Fresh CLSM Properties

<table>
<thead>
<tr>
<th>Mixture designation</th>
<th>FA-Ref</th>
<th>FA-Ref-2</th>
<th>FA-WR</th>
<th>FA-WR-2</th>
<th>FA-C1</th>
<th>FA-C1-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibrous residual</td>
<td>(None)</td>
<td>(None)</td>
<td>WR</td>
<td>WR</td>
<td>C1</td>
<td>C1</td>
</tr>
<tr>
<td>Cement (kg/m³)</td>
<td>75</td>
<td>179</td>
<td>25</td>
<td>27</td>
<td>21</td>
<td>29</td>
</tr>
<tr>
<td>Class C fly ash (kg/m³)</td>
<td>1213</td>
<td>1612</td>
<td>811</td>
<td>877</td>
<td>692</td>
<td>923</td>
</tr>
<tr>
<td>Sand, SSD (kg/m³)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fibrous residual (kg/m³)</td>
<td>0</td>
<td>0</td>
<td>167</td>
<td>181</td>
<td>285</td>
<td>190</td>
</tr>
<tr>
<td>Water (kg/m³)</td>
<td>496</td>
<td>645</td>
<td>522</td>
<td>456</td>
<td>445</td>
<td>444</td>
</tr>
<tr>
<td>W/Cm</td>
<td>0.39</td>
<td>0.36</td>
<td>0.62</td>
<td>0.50</td>
<td>0.62</td>
<td>0.47</td>
</tr>
<tr>
<td>Flow (mm)</td>
<td>335</td>
<td>415</td>
<td>380</td>
<td>230</td>
<td>235</td>
<td>275</td>
</tr>
<tr>
<td>Air content (%)</td>
<td>0.8</td>
<td>1.2</td>
<td>n. a.</td>
<td>3.1</td>
<td>3.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>1780</td>
<td>2440</td>
<td>1530</td>
<td>1540</td>
<td>1440</td>
<td>1590</td>
</tr>
</tbody>
</table>
Mixture Proportions and Fresh Properties of Ash Slurry

• The ash slurry mixtures made with fibrous residuals contained a lower amount of cementitious materials (cement + fly ash) than the reference ash slurry mixtures made without fibrous residuals.

• This was mainly because fibrous residuals are lightweight and increased the volume of CLSM produced.
Mixture Proportions and Fresh Properties of Ash Slurry (cont’d)

• The fly ash slurry mixtures FA-Ref and FA-Ref-2 made without fibrous residuals were not easy to handle - fast-setting and agglomeration while mixing.

• Fly ash slurries containing fibrous residuals were easy to produce and handle.
Mixture Proportions and Fresh Properties of Ash Slurry (cont’d)

- The fly ash slurry mixtures made with fibrous residuals remained workable while specimens were being cast.
Ball-Drop Diameter of CLSM

- To be suitable for load application, the ball-drop diameter on CLSM (ASTM D 6024) should be 75 mm (3 in.) or less [ACI-229 1999].
ASTM D 6024 Ball-drop test

Center for By-Products Utilization
ASTM D 6024 Ball-drop impressions

Center for By-Products Utilization
Ball-drop diameter on fly ash flowable slurry
Compressive Strength of CLSM

Unconfined compressive strength of CLSM (ASTM D 4832) should be [ACI-229 1999]:

- 0.35 to 0.7 MPa (50 to 100 psi) for backfills to allow for manual excavation
- \( \leq 2.1 \) MPa (300 psi) to allow for excavation by using a backhoe
- 2.8 to 8.3 MPa (400 to 1200 psi) for pavement bases.
## Compressive Strength of Fly Ash Flowable Slurry (MPa)

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>FA-Ref</th>
<th>FA-Ref-2</th>
<th>FA-WR</th>
<th>FA-WR-2</th>
<th>FA-C1</th>
<th>FA-C1-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.45</td>
<td>0.46</td>
<td>0.16</td>
<td>0.45</td>
<td>0.10</td>
<td>0.68</td>
</tr>
<tr>
<td>7</td>
<td>0.48</td>
<td>0.43</td>
<td>0.20</td>
<td>0.60</td>
<td>0.10</td>
<td>0.73</td>
</tr>
<tr>
<td>28</td>
<td>0.63</td>
<td>0.66</td>
<td>0.26</td>
<td>0.66</td>
<td>0.12</td>
<td>0.90</td>
</tr>
<tr>
<td>56</td>
<td>6.52</td>
<td>8.52</td>
<td>0.28</td>
<td>0.89</td>
<td>0.13</td>
<td>0.88</td>
</tr>
<tr>
<td>91</td>
<td>8.82</td>
<td>8.87</td>
<td>0.32</td>
<td>0.99</td>
<td>0.14</td>
<td>0.91</td>
</tr>
<tr>
<td>182</td>
<td>9.35</td>
<td>13.84</td>
<td>0.71</td>
<td>1.14</td>
<td>0.55</td>
<td>n. a.</td>
</tr>
</tbody>
</table>
Compressive Strength of Ash Slurry

- The fly ash slurry mixtures containing fibrous residuals (Mixtures FA-WR, FA-WR-2, FA-C1, and FA-C1-2) maintained a controlled low long-term strength (0.14 to 0.99 MPa at 91 days and 0.55 to 1.44 MPa at 182 days).
Sealing Test Specimen in Preparation for Hydraulic-Conductivity Test

Center for By-Products Utilization
Hydraulic Conductivity (Water Permeability)

The hydraulic conductivity of hardened flowable slurry was determined in accordance with ASTM D 5084 using falling head and constant tailwater elevation.
Hydraulic conductivity of fly ash flowable slurry
CONCLUSIONS

• Fibrous residuals improved workability of fly ash slurry. → Easier (less time-consuming) to thoroughly mix the ingredients.

• Fibrous residuals prevented rapid setting of the fly ash slurry mixtures made with Class C fly ash and kept the fresh ash slurry mixtures workable while they were being placed.
• Fibrous residuals helped the fly ash and sand slurry mixtures to set at an early age and maintain a low long-term strength, allowing for future excavation.

• Use of fibrous residuals, especially C1, was helpful in reducing the hydraulic conductivity of sand flowable slurry.
Thank you very much for your interest.
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