GEOPOLYMER COATING FOR THE REHABILITATION OF CONCRETE-BASED WASTEWATER COLLECTION SYSTEMS

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LOUISIANA TECH UNIVERSITY
The Trenchless Technology Center located within Louisiana Tech University is the first academic research center to be established in North America to support the growth of trenchless technology through research and education.
Trenchless Technology is a family of methods for the installation, rehabilitation and replacement of new or existing underground facilities with minimal disruption of land and services, low costs and low environmental impact.
One of the main objectives of TTC research is to find novel solutions for the rehabilitation of sewer pipes and other underground utilities like manholes.
THE SPRAY LINING TECHNIQUE
ACTUAL MATERIALS USED IN TT PROJECTS

EPOXY/POLYMERS

Advantages:
Corrosion resistance
Smooth surface
High strength

Disadvantages:
Adhesion
Cost
Thermal expansion

CEMENTITIOUS

Advantages:
Lower costs
Easy application
Good adhesion

Disadvantages:
Low corrosion resistance
Rough surfaces
Interconnected porosity
Lower density

GEOPOLYMER!
RESEARCH PLAN

• Study the impact of several variables on the properties of geopolymers:
  • Raw material selection from local sources
  • Composition of the alkaline solution
  • Curing regime

• To enable geopolymer to be applied as a cementitious coating with existing cementitious spray technology.

• To perform field tests in confirmation of lab results.

• To produce an optimal formulation to be used in real scale projects.
# RAW MATERIALS

<table>
<thead>
<tr>
<th>Oxide</th>
<th>Metakaolin, wt %</th>
<th>Class C Fly Ash, wt %</th>
<th>Class F Fly Ash, wt%</th>
<th>OPC, wt %</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO2</td>
<td>54.26</td>
<td>48.7</td>
<td>50.25</td>
<td>26.12</td>
</tr>
<tr>
<td>Al2O3</td>
<td>39.82</td>
<td>16.6</td>
<td>22.56</td>
<td>4.25</td>
</tr>
<tr>
<td>Fe2O3</td>
<td>2.91</td>
<td>6.93</td>
<td>20.0</td>
<td>3.65</td>
</tr>
<tr>
<td>CaO</td>
<td>0.70</td>
<td>18.72</td>
<td>2.1</td>
<td>58.51</td>
</tr>
<tr>
<td>MgO</td>
<td>1.51</td>
<td>3.91</td>
<td>0.00</td>
<td>1.59</td>
</tr>
<tr>
<td>SO3</td>
<td>0.01</td>
<td>0.85</td>
<td>0.50</td>
<td>2.36</td>
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<tr>
<td>LOI</td>
<td>0.72</td>
<td>0.49</td>
<td>2.48</td>
<td>2.67</td>
</tr>
<tr>
<td>Na2O</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.14</td>
</tr>
<tr>
<td>K2O</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.52</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>99.93</strong></td>
<td><strong>96.2</strong></td>
<td><strong>97.89</strong></td>
<td><strong>99.8</strong></td>
</tr>
<tr>
<td>SiO2/Al2O3</td>
<td>1.36</td>
<td>2.93</td>
<td>2.23</td>
<td>6.15</td>
</tr>
<tr>
<td><strong>SiO2 + Al2O3</strong></td>
<td><strong>94.08</strong></td>
<td><strong>65.30</strong></td>
<td><strong>72.81</strong></td>
<td><strong>30.37</strong></td>
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</tbody>
</table>
COMPRESSIVE STRENGTH

<table>
<thead>
<tr>
<th>DAYS</th>
<th>Class C F.A.-Geop</th>
<th>Class F F.A.-Geop</th>
<th>OPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>4000</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td>6000</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td>8000</td>
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</table>
VISUAL APPEARANCE
## DESIGN OF EXPERIMENTS

<table>
<thead>
<tr>
<th>RESEARCH VARIABLE</th>
<th>LEVELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicate type</td>
<td>D, N and Star</td>
</tr>
<tr>
<td>Hydroxide molarity</td>
<td>6, 10 and 14</td>
</tr>
<tr>
<td>Silicate/Hydroxide ratio</td>
<td>1, 2, 3</td>
</tr>
</tbody>
</table>

### FIXED PARAMETERS

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly ash type</td>
<td>Class F</td>
</tr>
<tr>
<td>Fly ash:sand ratio</td>
<td>1:1</td>
</tr>
</tbody>
</table>

### RESPONSE VARIABLE

<table>
<thead>
<tr>
<th></th>
<th>NORM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength in cubes</td>
<td>ASTM C-109</td>
</tr>
<tr>
<td>Remaining compressive strength</td>
<td>ASTM C-267</td>
</tr>
<tr>
<td>Mass loss</td>
<td>ASTM C-267</td>
</tr>
<tr>
<td>Flow</td>
<td>ASTM C-1437</td>
</tr>
</tbody>
</table>
SPRAYING TESTS

• A number of additives was tried to evaluate their effect on geopolymer’s viscosity and other rheological parameters.

• Lab tests modifying the concentration and % of addition were performed to help tune the amount and type of additive to be used.

• An important control in geopolymer’s viscous behavior was obtained after a number of tests.

• Field tests were conducted to prove results obtained in the lab.
SPRAYING TESTS

DYNAMIC VISCOSITY

VISCOSITY (cPoise)

TIME (s)

- NO ADDITIVE
- S12510
- S12520
- S12530
GEOPOLYMER SURFACE TENSION

- 0%
- 10%
- 20%
- 30%

Addition level

Surface tension (mN/m)

0.00%
0.50%
1.00%
1.50%
2.00%

0.00  20.00  40.00  60.00  80.00  100.00  120.00
RESULTS – FIELD TESTS
RESULTS – FIELD TESTS
RESULTS – FIELD TESTS

• Geopolymer samples stored inside manhole in Pensacola, FL

• Manhole is re-coated every six months with Portland cement.

• Geopolymer samples did not experience mass loss in six months.
CORROSION RESISTANCE

![Graph showing remaining compressive strength over weeks for different materials: Class F Fly ash Geopolymer, OPC, and Coating.](image-url)
TAKING GEOPOLYMER TO THE FIELD

• Currently working to take prototype to the field

• Short term goals to reduce curing time and increase thickness of spray

• First real manhole applications within the next months.

• These tests will take place in the cities of Cincinnati and St. Louis.
SUMMARY AND CONCLUSIONS

• A novel geopolymer-based cementitious product prototype was developed at Louisiana Tech as an alternative material for Trenchless rehabilitation projects.

• This represents the first time that geopolymers are considered for Trenchless rehabilitation projects.

• The modification of geopolymer’s surface tension proved to be a substantial aid to solve geopolymer workability problems.

• Real life manhole rehabilitation projects will be performed during this year.

• We expect geopolymer to gain reputation as an excellent rehabilitation material and to be used by contractors as one of their choices when bidding for projects.