Greening Cement-Based Products with Waste Powder Paint (WPP)

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PROBLEM STATEMENT AND SIGNIFICANCE

- Powder paint is used in many industries including automotive and furniture manufacturing industries. During its application, a significant amount is wasted. The waste powder paint (WPP) amounts to 1.5 million pounds per year from 6 companies alone, in Michigan (GMI 2012).
- Recycling process of WPP is challenging because of the degradation of re-processed powder in powder paint and the high volume of waste exceeding the capacity of outlets. Thus, restricting to dispose the WPP in landfills.
- Industry byproducts have been used in cement-based products for improving the properties of the latter. Therefore, there is a possibility of using WPP in cement-based products, without processing.
- Investigation is necessary for the WPP usage in cement-based products.

OBJECTIVE AND SCOPE

- The overall objective of the research project is to investigate the influence/interaction of WPP, cement, supplementary cementitious materials (SCMs), and chemical admixtures on the fresh, hardened, and durability properties of the cement-based products. Also, to standardize the WPP application, reduce WPP getting into landfills, and conserve cement usage.
- The scope of the preliminary studies is limited to evaluating fresh and hardened properties of cement-based products, such as grout, with WPP.

CHEMICAL AND PHYSICAL PROPERTIES

- The WPP is made of different types of polymers (Figure 2) and has characteristics analogous to cement admixtures. The cement-based industry has a proven track record of using fibers, polymers and polymer-modified particles to improve concrete, grout, mortar, and masonry properties.
- About 95% of cement particles are smaller than 45 μm (PCA 2003). Hence, WPP size (Figure 3) is comparable to cement.
- WPP has three different transition temperature ranges (shown below) (Gaweo and Rettig 2002).
  - Glass transition temperature of WPP: 30°C – 60°C
  - Rubber-elastic state temperature of WPP: 50°C – 100°C
  - Melting temperature of WPP: 90°C – 190°C

HEAT OF HYDRATION TEST

- Comparing the test results (Figure 4) with the typical curve (Figure 5), a dormant period of around 2.5 hrs was observed for all the mixes.
- Reduction of about 22.4% and 29.1% in the maximum hydration temperature for the 10% and 20% WPP mixes was observed, compared to 0% WPP mix.

Table 1. Test Details

<table>
<thead>
<tr>
<th>ASTM Standards</th>
<th>W/C ratio</th>
<th>Type-I cement (g)</th>
<th>Water (ml)</th>
<th>Air as a cement replacement (%)</th>
<th>Micro-air-temperature (°C)</th>
<th>Weight of the test specimen (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM C231 &amp; ASTM C115</td>
<td>0.45</td>
<td>600</td>
<td>270</td>
<td>0</td>
<td>15 - 20</td>
<td>750</td>
</tr>
</tbody>
</table>

Compressive strength values were found to be equivalent for the specimens (Table 3), without external curing.

Table 3. Compressive Strength Results

<table>
<thead>
<tr>
<th>Specimen</th>
<th>C/S area (cm²)</th>
<th>Volume of test specimen (cm²)</th>
<th>Diameter of test specimen (cm)</th>
<th>Weight of test specimen (g)</th>
<th>Volume of cement grout (cm³)</th>
<th>Diameter of cement grout (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% WPP</td>
<td>39.77</td>
<td>358.72</td>
<td>7.97</td>
<td>7.96</td>
<td>378.32</td>
<td>7.96</td>
</tr>
<tr>
<td>10% WPP</td>
<td>49.81</td>
<td>460.00</td>
<td>8.15</td>
<td>8.07</td>
<td>428.32</td>
<td>8.07</td>
</tr>
<tr>
<td>20 % WPP</td>
<td>69.85</td>
<td>538.72</td>
<td>8.24</td>
<td>8.09</td>
<td>518.32</td>
<td>8.09</td>
</tr>
</tbody>
</table>

Early Age Shrinkage/Expansion Test

- Generally, the cement grout is expected to shrink at the early age. But during the casting of the cement grout specimens with WPP, an unusual phenomenon of cement grout expansion was observed (Figures 8 & 9).
- Equal weights of cement grout mixture were used to cast the WPP specimens. The 0% WPP specimen started shrinking after the starting test, whereas, the specimens with 10% and 20% WPP started expanding after 10 to 15 min delay (Figure 9). The expansion of WPP specimens ceased after 2.5 hrs. Considering the heat of hydration curves (Figures 4 & 5), it can be inferred, expansion occurred before initial setting.

Table 5. Test Details

<table>
<thead>
<tr>
<th>ASTM Standard</th>
<th>W/C ratio</th>
<th>Water (ml)</th>
<th>WPP as a cement replacement (%)</th>
<th>Micro-air-temperature (°C)</th>
<th>Weight of the test specimen (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM C186 &amp; ASTM C1074</td>
<td>0.45</td>
<td>600</td>
<td>0</td>
<td>15 - 20</td>
<td>750</td>
</tr>
</tbody>
</table>

Figure 8. Expansion of cement grout with WPP mix. The WPP specimens were casted into two portions (Figure 10) to be used for this test.

Figure 9. Percentage change in height of WPP mix specimens

CONCLUSIONS AND FUTURE RESEARCH

- Cement grout with 20% WPP expands immensely, thus, there is a great potential of using WPP to develop shrinkage-compensating admixture for mitigating several issues that are observed due to shrinkage.
- Porosity of the cement grout specimen with WPP can be improved by heating it up to a temperature that is in the melting temperature range of WPP.
- Less dense specimens were certainly a factor for reduced strength. Thus, evaluating impact of confining pressure on strength development is vital.
- Impact of adding aggregates and the chemical reactions, in cement & WPP mixture in liquid form need to be understood from future research.
- The outcome of the research could allow WPP to be used in several civil engineering applications, such as grouting precast connections & underpinning.

ACKNOWLEDGEMENT & DISCLAIMER

Acknowledgement: This work was supported by the Department of Energy under Award number DE-SC0005363.

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