Introduction

- Wildfires in the U.S. have caused severe damage and property losses.
- The fire resistance of structures and buildings is critical and in great need.
- Conventional intumescent coatings have some limitations (e.g., vulnerable to the environmental, toxic, and expensive).
- Innovative surface-bonded fire-resistant coating needs to be developed.
- Portland cement, geopolymer, and magnesium phosphate cement are proved to be inert, but few studies were focused on using them as fire-resistant coatings.

Objective

- To develop mix designs of innovative fire-resistant coating materials (high performance cement mortar (HPCM), geopolymer mortar (GPM), and magnesium phosphate mortar (MPCM)) using cement mortar, geopolymer and magnesium phosphate cement.
- To explore the feasibility of using HPCM, GPM, and MPCM as a fire-resistant coating material for structures with three primary features: (a) good workability for application, (b) enough adhesion to the surface of the structure, and (c) excellent fire resistance.

Screening Tests

- Orthogonal arrays developed using Taguchi method to identify critical factors and levels in mix design.
- Screening tests
  - Compressive strength
  - Workability
  - Setting time
- Determining the optimum mix using MinTab
- Optimum mix designs
  - HPCM
  - GPM
  - MPCM

<table>
<thead>
<tr>
<th>Factors</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water/binder</td>
<td>0.32</td>
<td>0.35</td>
<td>0.38</td>
</tr>
<tr>
<td>Accelerator/binder</td>
<td>0.07</td>
<td>0.01</td>
<td>0.013</td>
</tr>
<tr>
<td>VMA/binder</td>
<td>0.00</td>
<td>2.00</td>
<td>4.00</td>
</tr>
<tr>
<td>GPM: Binder/alkali activator solution</td>
<td>2.00</td>
<td>2.50</td>
<td>3.00</td>
</tr>
<tr>
<td>Na2SiO3/NaOH</td>
<td>2.00</td>
<td>2.50</td>
<td>3.00</td>
</tr>
<tr>
<td>Magnesium phosphate (molar ratio)</td>
<td>6.00</td>
<td>8.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Borax/Binder</td>
<td>0.00</td>
<td>0.05</td>
<td>0.10</td>
</tr>
<tr>
<td>Water/binder</td>
<td>0.20</td>
<td>0.22</td>
<td>0.24</td>
</tr>
</tbody>
</table>

| Equipment for fire resistance test

| Cylindrical specimens made with HPCM, GPM, and MPCM were exposed to elevated temperatures in a ventilated furnace to investigate their fire resistance.
| The heat transfer rates of HPCM, GPM, and MPCM were determined and compared.

Results

- All three materials met construction requirements (i.e., compressive strength > 8.96 MPa, 170mm flow table spread < 230mm, and initial setting time < 6.5 hrs. At these range, the material had adequate strength, good workability and fast setting to ensure the material can stick on structure surfaces).
- HPCM had the highest compressive strength, followed by MPCM, and then GPM.
- Slip resistance, cohesiveness and adhesiveness

Performance Tests

- Materials: Optimum mix of HPCM, GPM, and MPCM from screening tests
- Compressive strength, workability, and setting time tests
- Slip resistance, cohesiveness and adhesiveness tests

| Performance equipment

| The fresh mortar was poured into a compressed air sprayer and then sprayed to the surface of a wood pad vertically placed.
| Slip resistance was measured using the sprayed mortar area change on the wood.
| Cohesiveness was measured using the sprayed mortar’s build-up thickness.
| Adhesiveness was measured using rebound after spraying.

Conclusions

- Three fire-resistant coating materials with optimum mix designs were developed.
- HPCM, GPM, and MPCM all met basic construction requirements as coating materials (compressive strength, workability, setting time, slip resistance, cohesiveness, and adhesiveness).
- HPCM, GPM, and MPCM could withstand the temperature up to 650°C, 950°C, and 1000°C, respectively.
- HPCM had alligator cracks at 650°C and spalling problem at 1000°C, GPM had a few cracks at 1000°C, and MPCM had no crack at 1000°C. MPCM showed the best integrity after heating.