THE INFLUENCE OF A SUPER PLASTICIZER ON RECYCLED GYPSUM PLASTER PROPERTIES

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Abstract

The gypsum plaster waste is generated during the components production and building construction processes. This material should be recycled to avoid the contamination of soil and groundwater. The reactions reversibility enables the recycling of the material by a simple recycling process which produced a recycled gypsum plaster. However, the recycled gypsum has shown a reduction in workability. This waste material needs to ensure the workability to be applied to components production. In this way, this study analyses the influence of using a superplasticizer on the properties of recycled gypsum plaster. The properties were evaluated in fresh (consistency and setting times) and in hardened state (compressive strength, air permeability and microstructure). Results show better workability with the superplasticizer content, but the strength diminished significantly. The setting times were increased with increasing the admixture content and the microstructure showed the formation of large dihydrate crystal during recycled gypsum plaster hydration.

1. INTRODUCTION

Construction gypsum plaster is a binding material with large use in building construction. The chemical composition of this material is calcium sulphate hemihydrate (CaSO$_4$·0.5H$_2$O), Anhydrite III (CaSO$_4$·$\varepsilon$H$_2$O, with 0.06 < $\varepsilon$ < 0.11), Anhydrite II (CaSO$_4$), calcium sulphate dihydrate (CaSO$_4$·2H$_2$O) and smaller amounts of impurities [1], [2], [3].

In Brazil, the chemical composition of the commercial gypsum plaster is hemihydrate (54.8% - 96.2%), Anhydrite III (0.0% - 19.0%) and dihydrate (0.0% - 10.0%). It is used in

\[
\text{CaSO}_4\cdot2\text{H}_2\text{O} + \text{heat (140 °C - 160 °C)} \rightarrow \text{CaSO}_4\cdot0.5\text{H}_2\text{O} + 1.5\text{H}_2\text{O} \quad (1)
\]
building constructions as pastes for wall renderings, for components (plasterboards, masonry blocks and ceilings) and for decorative elements [1], [2].

In contact with water, gypsum hemihydrate particles react (hydration reaction) and become a hard mass by an exothermic reaction, showed in (2) [4].

\[
\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O} + 1.5\text{H}_2\text{O} \rightarrow \text{CaSO}_4 \cdot 2\text{H}_2\text{O} + \text{heat} \quad (2)
\]

In Brazil, there is a significant amount of gypsum plaster waste: 4% to 15% of construction and demolition waste [5], and values up to 47% of material loss when used as wall rendering [6].

This waste material is mainly composed of calcium sulphate dihydrate (\(\text{CaSO}_4 \cdot 2\text{H}_2\text{O}\)) which is not inert and contaminates soil and groundwater. Brazilian Environmental Legislation establishes that the gypsum waste can be recycled or placed in special landfills.

Due to the chemical characteristics of gypsum plaster waste; this material can be recycled as a binding material by a simple recycling process, similar to the industrial process [5]. Recent studies showed similar characteristics between recycled gypsum plaster (RGP) and commercial gypsum plaster (CGP) assessed by thermal analyses (TG/DTG) [7] and crystal morphology (SEM) [8], as well as it can be recycled successively [9].

In spite of that, there is a lack of information about the behaviour of this recycled material. Pinheiro [5] has found a reduction on the workability of the recycled gypsum plaster (RGP), and to be used in buildings this property is very important.

The RGP in the production of components for buildings is necessary to obtain an adequate workability for component moulding. It can be reached by using an admixture that modifies the material properties in fresh and hardened states. In this way, this work aims to study the influence of a superplasticizer (polycarboxylate) on RGP properties.

2. HYDRATION, WORKABILITY AND PROPERTIES

The mechanism of gypsum hydration has been explained by the theory of crystallization described by Lavoisier in 1798, and by Le Chatelier in 1877, whereas the gypsum crystallization occurred in the saturated solution of the hemihydrates. The chemical phenomenon had three steps: the chemical phenomenon of hydration; the physical phenomenon of crystallization; and the mechanical phenomenon of hardening [4].

When mixing with water, hemihydrate (\(\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O}\)) dissolves in water, forming a saturated solution of \(\text{Ca}^{2+}\) and \(\text{SO}_4^{2-}\) ions, followed by precipitation of acicular dihydrate crystals (\(\text{CaSO}_4 \cdot 2\text{H}_2\text{O}\)). So, the crystallization nuclei are formed and around it the crystals grow, forming an interlocking net of long crystals providing the strength of the material [10], [11].

During the hydration process the microstructure of the hardened paste is defined. It depends on plaster constituents, the water/gypsum ratio and the admixtures used.

Initially, the water/gypsum ratio is responsible to lead the hydration reactions and to keep the workability/fluidity of gypsum slurry. In general, when the water content increases the void fractions also increase, and the bond between the gypsum crystals decrease, leading to lowering the strength of the material [12], [13].

To achieve the workability/fluidity required for gypsum plaster it is also employed certain types of admixtures. The admixtures often used to improve the workability of plaster are retardants that increase the time available for its handling, and superplasticizers, which provide the fluidity/plasticity necessary for moulding [14], [15].

Superplasticizers, when added to gypsum paste, modify the mechanism of the RGP hydration. The admixture is chemically adsorbed on the surface of calcium sulphate
hemihydrate grains, slowing down the dissolution process, the formation of nucleation sites and the crystal growth, resulting in changing the material microstructures decreasing their physic and mechanical properties [16].

3. MATERIALS AND METHODS

3.1 Materials

The process to obtain the RGP is followed [5]: The gypsum plaster waste (GPW) was ground in a ball mill reaching a fineness modulus less than 1.10. After grinding the powder was calcined in a stationary kiln at 150 °C for one hour, obtaining the RGP. Tables 1 and 2 show the physical properties and chemical characteristics of RGP, respectively.

Table 1: Physical properties of recycled gypsum plaster.

<table>
<thead>
<tr>
<th>Material</th>
<th>Fineness modulus</th>
<th>Bulk unit weight (kg/m³)</th>
<th>Specific gravity (kg/m³)</th>
<th>Specific surface area (m²/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGP</td>
<td>0.38</td>
<td>429</td>
<td>2550</td>
<td>6345</td>
</tr>
</tbody>
</table>

Table 2: Physical properties of recycled gypsum plaster.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass (%)</th>
<th>Levels (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Free water</td>
<td>Water crystallization</td>
</tr>
<tr>
<td>RGP</td>
<td>0.85</td>
<td>2.96</td>
</tr>
</tbody>
</table>

The superplasticizer used in this experimental work was a polycarboxylate based admixture. The solids are 21.88%, determined by drying in infrared light balance.

3.2 Methods

Pastes were produced with a water/plaster ratio of 0.7. The content of superplasticizer used were 0%, 1%, 1.5%, 1.75%, 2.0% and 2.2%.

It was observed: the consistency by the mini-slump test [5], setting times by Vicat needle [17], compressive strength [18], air permeability [5] and SEM observations.

4. RESULTS AND DISCUSSION

4.1 Superplasticizer content

Table 3 shows the values of mini-slump test (spreading) and compressive strength from the pastes with 0%, 1%, 1.5%, 1.75%, 2.0% and 2.2% of superplasticizer content.

The RGP increased the workability/fluidity by increasing the spreading of the paste. On the other hand, the compressive strength decreased with increasing the admixture content, as reported by Millán [15] and Sing and Middendorf [16].
Table 3: Spreading and compressive strength results from RPG pastes with different superplasticizer content.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Pastes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RGP-0</td>
</tr>
<tr>
<td>Spreading (mm)</td>
<td></td>
</tr>
<tr>
<td>0 ideal</td>
<td>0.0</td>
</tr>
<tr>
<td>Compressive Strength (MPa)</td>
<td></td>
</tr>
<tr>
<td>6.2 ideal</td>
<td>6.2</td>
</tr>
</tbody>
</table>

4.2 Microstructure evaluation

The microstructure was evaluated on the RPG pastes whose results of spreading (higher than 70 mm) and compressive strength were suitable for the production of components (good workability and minimum value of compressive strength according to the Standards). In this case it was chosen the mixture RPG-1.5. This mixture had spreading of 71 mm and compressive strength of 3.8 MPa (Table 3). Results of setting times are important to these pastes to know how long they maintain the workability to make the components (Table 4).

Table 4: Results of spreading and setting times from RGP pastes with 0% and 1.5% of superplasticizer

<table>
<thead>
<tr>
<th>Paste</th>
<th>Spreading (mm)</th>
<th>Setting times (min)</th>
<th>Air permeability (mm²)</th>
<th>Compressive strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>start (t₁)</td>
<td>end (t₂)</td>
<td>∆t (t₂ - t₁)</td>
<td></td>
</tr>
<tr>
<td>RGP-0</td>
<td>0</td>
<td>12</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>RGP-1.5</td>
<td>71</td>
<td>28</td>
<td>36</td>
<td>8</td>
</tr>
</tbody>
</table>

These results show that the setting times increased with the admixture, showing more time to work with the RPG paste and diminishing the possibility to this mixture be lost and produce again gypsum plaster waste.

The compressive strength to make components is in accordance with the Brazilian Standards for soil-cement blocks (2 MPa) [19] and ceramic block (1MPa) [20].

The air permeability increased significantly (8.5 times) showing the high permeability and the possibility of fungal growth; so, this component must be protected. But this high permeability can improve the thermal comfort inside the ambient when using blocks made of RGP.

Figure 1 shows the microstructure of the RGP pastes without and with admixture. The crystal formation is quite different. In the RGP without superplasticizer the crystals are needle like with thickness dimensions varying from 1 μm to 2.5 μm, while the paste RGP-1.5 with 1.5% of superplasticizer the thickness are higher than 3 μm, the pores are large and prismatic. There is not the interlocking of crystals to bring the necessary bond to improve the RGP properties.

When the RGP has superplasticizer addition, results can be summarised as follows: (i) an increase in the workability/fluidity of the material; (ii) retarding the setting time; (iii) an increase in the air permeability; and (iv) decrease in compressive strength with respect to the RGP-0.
The superplasticizer addition modifies the hydration mechanism of the material. The admixture is chemically adsorbed on the hemihydrate surface becoming slower the process of dissolution, the formation of nucleation sites, crystal growth and hardening [11], [15], [16]. So, the same occurred with RGP-1.5 paste: an increase in the workability/fluidity and the retarding of setting time.

Figure 1. Microstructure morphology obtained by SEM from (a) RGP-0 and (b) RGP-1.5.

During the hydration mechanism the microstructure of hardened gypsum plaster is formed. It is constituted by interlocking dihydrate crystals in the form of plates and needles with high content of voids. This microstructure arrangement leads the physic-mechanical properties of hardened plaster [12].

When superplasticizer is added to the RGP, it modifies the morphology and habit of growing crystals resulting in microstructures formed by larger and less interlocked crystals, with high voids content. This new microstructure arrangement results in changes, increasing the porosity and reducing the mechanical properties of the resulting material [16].

The RGP–1.5 presented an increase in the air permeability and decrease in compressive strength in relation to RGP–0. The change of microstructure (Figure 1) is similar as related by Sing and Middendorf [16].

5. CONCLUSIONS

This work studied the influence of superplasticizer admixture on the properties of recycled gypsum plaster (RGP). The superplasticizer addition on RGP pastes had the following.

- Increased the workability/fluidity and decreased the compressive strength of RGP;
- The setting times were increased; and increase the air permeability;
- The microstructure of RGP-1.5 had large dihydrate crystals, with low interlocking, and high content of voids.

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REFERENCES


