Reducing the clinker factor in masonry cements

Reducing the clinker factor is one of the key strategies for lowering the environmental impact of cement production. The specific characteristics of masonry cement require a customised approach to lowering the clinker factor.

by Olivier Malbault, CHRYSO Group, France

Masonry cement was developed in the late 1920s to simplify and optimise the mortar making process on site. Nowadays, this niche market represents 0.1-10 per cent of the local cement market depending on the country.

Generally, masonry mortars are produced by blending masonry cement, sand and water, for use in brick, block and stone masonry construction.

The main properties required are:
- workability
- water retention
- durability
- setting time
- adhesion to underlying surface.

Water retention resides in the mortar’s ability to retain its mixing water under suction. This property gives the mason enough time to lay units and make any adjustment before the mortar hardens.

Water retention can be enhanced by increasing the amount of limestone/lime or air into the mortar. Mortars with a higher water retention rate are suitable for use with high suction rate units. Meanwhile, on the other hand, mortars with a lower water retention rate are more adapted for use with low suction rate units.

Even if the ingredients for masonry cement vary from one manufacturer to another, masonry cement contains three main components:
- Portland cement – to obtain high strengths and setting time
- limestone or lime used as plasticisers – to increase workability
- air-entraining cement additives – for improved workability and durability, with generally a high level of limestone.

There are four different masonry cement mortar classes according to physical requirements, which follow the standards of ASTM C-270 for the US and EN 413-1 in Europe. Table 1 shows a comparison of the US and European masonry cement mortars’ main characteristics.

The CHRYSO Group has historically been providing air-entraining agents to help cement manufacturers produce masonry cement with the appropriate properties, mainly in terms of workability, water retention and productivity.

Air entrainment in masonry cement mortar

Air entrainment is a complex phenomenon, especially in a cementitious environment, which requires the use of surfactant. During hydration, the cement grains are quickly surrounded by a layer of calcium ions onto which the surfactant will adsorb thanks to its anionic group (see Figure 1). The surfactant, composed by hydrophobic and hydrophilic groups, stabilises air bubbles in masonry cement by reducing air/water interface tension within the cement paste. Adsorption of surfactant at the air/water interface is directly driven by the higher affinity for air of the hydrophobic part and the higher affinity for water of the

<table>
<thead>
<tr>
<th>Cement type (ASTM C-270)</th>
<th>Air content (%)</th>
<th>Water retention (%)</th>
<th>7-day strength (MPa)</th>
<th>28-day strength (MPa/psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>X ≤ 18</td>
<td>X ≥ 75</td>
<td>X ≥ 17.2/2500</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>X ≤ 18</td>
<td>X ≥ 75</td>
<td>X ≥ 12.4/1800</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>X ≤ 20</td>
<td>X ≥ 75</td>
<td>X ≥ 5.2/750</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>X ≤ 20</td>
<td>X ≥ 75</td>
<td>X ≥ 2.4/350</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: main characteristics of US and European masonry cement mortars
hydrophilic group. The formation of air bubbles in the cement paste is more stable and uniformly dispersed thanks to the protection created around it. Surfactant also reduces the surface tension of water, therefore easing the formation of air bubbles in the cement paste.

Surfactants can be present in water, at air/water and cement/water interfaces. Without the surfactant, air bubbles tend to coalesce to form larger bubbles which have a greater tendency to escape from the paste due to their lower density.

To appreciate the impact of air content on strength development in masonry cement mortar, a study has been conducted by introducing a growing level of surfactant in a MC 12.5 masonry cement composition containing 40 per cent of limestone. During the entire study, cement fineness was measured between 5700-5800cm²/g.

As anticipated, increasing air content in masonry mortar cement decreases the level of the 28-day strength (see Figure 2). This highlights the difficulty of designing masonry cement composition with the right balance between strength and air content, which intimately drives the workability of the masonry mortar.

**Lowering clinker content in masonry cement**

Over the last decade, the cement industry has moved forward and new regulations regarding carbon tax regulations have been implemented around the world. Using higher volumes of alternative fuel and substituting cementitious materials has become one of the key performance indicators (KPIs) followed by cement producers.
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manufacturers. On account of this trend, CHRYSO Group has identified a new technology and developed a new product that enables a reduction in the clinker factor in masonry cement while respecting the physical requirements of masonry cement mortar standards.

In the context of this research, the impact of the limestone quality on strength development has been studied. This study has been enhanced by mixing CEM I type cement and limestone in different proportions. The gypsum amount in the CEM I type cement remained constant for this study while the fineness of CEM I type cement and limestone were 4000 and 6000cm²/g, respectively.

Unsurprisingly, a higher limestone content in cement drastically decreased the 28-day strength. Ranging from 35 to 60 per cent of limestone, 28-day strength versus CEM I type reference losses are –38 and –75 per cent, respectively. This loss of performance underlines the difficulty in lowering the clinker factor for masonry cement without decreasing the 28-day strength performance.

Case study: masonry cement with a lower clinker factor
This case study aims to improve the masonry cement process and quality using the recent CHRYSO® technology: CHRYSO® AEL. In this study CHRYSO AEL was compared to a standard air-entraining (SAE) agent in industrial conditions during a masonry cement production campaign. Primary work was carried out in the laboratory to define the appropriate air-entraining agent dosage to achieve the targeted air level.

All cement additives were introduced onto the feed conveyor belt and the analysis of production was conducted online, followed by the characterisation of masonry cement mortar properties. Table 2 shows that the highest performances were achieved with the latest generation of air-entraining cement additive which was specifically designed for masonry cement. In comparison with a conventional air entrainer and for the same fineness, using CHRYSO AEL dosed at 500ppm allowed to:

- increase productivity by 19 per cent
- reduce clinker content by four points
- raise water retention by seven per cent

while keeping the other masonry cement characteristics constant.

Moreover, the reduction of the mill media coating and improvement of cement flowability contributed to improved production and reduced maintenance costs. The cost of cement has also been reduced by lowering the amount of clinker.

Summary and benefits
The CHRYSO AEL technology combines:

- a powerful and robust air entraining technology
- charge neutralisation which allows for an easier diffusion breakage in the material to be ground, particles re-agglomeration limitation and a better flowability
- chemical cement activation.

As every cement plant has its own characteristics (including requirements, process, materials, cement composition and energy costs) and because masonry applications are numerous and complex, CHRYSO provides fine-tuning solutions with CHRYSO AEL to help masonry manufacturers reach their KPI objectives with greater ease.

REFERENCES

Table 2: CHRYSO® AEL performance in industrial conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TEST 1</th>
<th>TEST 2</th>
<th>TEST 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinker (weight %)</td>
<td>58</td>
<td>58</td>
<td>54</td>
</tr>
<tr>
<td>Gypsum (%)</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Limestone (%)</td>
<td>39</td>
<td>39</td>
<td>43</td>
</tr>
<tr>
<td>Air entrainer dosage (kg/t cement)</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Cement mill output (tph)</td>
<td>48</td>
<td>55</td>
<td>57</td>
</tr>
<tr>
<td>Reject (tph)</td>
<td>75</td>
<td>70</td>
<td>68</td>
</tr>
<tr>
<td>Residue 90µm (weight %)</td>
<td>1.9</td>
<td>1.8</td>
<td>1.9</td>
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<tr>
<td>Air content in fresh mortar (%)</td>
<td>11.5</td>
<td>11.3</td>
<td>11.6</td>
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<tr>
<td>7-day strength (MPa)</td>
<td>14.8</td>
<td>20.9</td>
<td>14.5</td>
</tr>
<tr>
<td>28-day strength (MPa)</td>
<td>19.0</td>
<td>24.4</td>
<td>19.2</td>
</tr>
<tr>
<td>Water retention (%)</td>
<td>85</td>
<td>90</td>
<td>91</td>
</tr>
</tbody>
</table>

Figure 3: 28-day strength deviation depending on the limestone content in cement

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