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Introduction

- Natural Hydraulic Lime (NHL) results from the calcination of crushed limestone containing clays (Figure 1 and 2). These are similar to the historic materials in terms of chemical compatibility and therefore adequate to use in conservation works. Different from air lime, NHL binders achieve a faster and stronger set due to the initial hydraulic reactions [1][2].
- Chemical and physical properties of NHL of a given manufacturer can change over time.
- BS EN 459-1:2010 classifies the NHL binders based on standard samples unrepresentative in their nature of the mortars used ‘on-site’ (Table 1).
- Cementation Index (CI) (Equation 1) and Hydraulicity Index (HI) (Equation 2) were used in the past to classify the NHL raw materials according to their potential hydraulic properties (Table 2) [3][4].
- Mortars from the same NHL class often exhibit distinct variations in properties, frequently presenting stronger mechanical properties than desired which can be harmful to historic fabric (Table 1). [4].

Materials

- Three classes of binders from 2 different manufacturers (X and Y) were compared.
- X-ray fluorescence and X-ray diffraction were used to characterise the NHL powders.
- The aggregate used was a common available well graded quartz sand.

Table 1: NHL binders analysed

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>NHL 2</th>
<th>NHL 3.5</th>
<th>NHL 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>X2</td>
<td>X3.5</td>
<td>X5</td>
</tr>
<tr>
<td>Y</td>
<td>Y2</td>
<td>Y3.5</td>
<td>Y5</td>
</tr>
</tbody>
</table>

Table 2: Cementation index for various types of lime

<table>
<thead>
<tr>
<th>Lime description</th>
<th>C.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat limes</td>
<td>close to zero</td>
</tr>
<tr>
<td>Slightly (fleebly) hydraulic limes</td>
<td>0.3 to 0.5</td>
</tr>
<tr>
<td>Moderately hydraulic limes</td>
<td>0.5 to 0.7</td>
</tr>
<tr>
<td>Eminently hydraulic limes</td>
<td>0.7 to 1.1</td>
</tr>
</tbody>
</table>

Mortars

- Mortar prisms were prepared using an horizontal pan mixer and cast in phenolic wood moulds.
- Water/binder and the mechanical strength at 28 days.

Table 4: Paste hydration and mechanical tests performed at the different ages.

<table>
<thead>
<tr>
<th>Water/binder</th>
<th>Spread (flow table)</th>
<th>Compressive strength per day (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(mass)</td>
<td>(mm)</td>
<td>7</td>
</tr>
<tr>
<td>X2</td>
<td>0.95</td>
<td>160</td>
</tr>
<tr>
<td>X3.5</td>
<td>1.31</td>
<td>161</td>
</tr>
<tr>
<td>X5</td>
<td>1.18</td>
<td>156</td>
</tr>
<tr>
<td>Y2</td>
<td>1.12</td>
<td>160</td>
</tr>
<tr>
<td>Y3.5</td>
<td>1.19</td>
<td>174</td>
</tr>
<tr>
<td>Y5</td>
<td>0.9</td>
<td>174</td>
</tr>
</tbody>
</table>

Conclusions

- BS EN 459-1 although useful for manufactures can be inadequate to be used as a guideline for design and specification of conservation mortars.
- There is the potential that the chemical and mineral composition can be used to predict mortar properties, but it needs to be correlated with the physical properties of the binder.

Acknowledgments

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