Electricity costs for grinding of cement with expanding additives

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Abstract

The most popular building material, including on transport facilities, is cement. Cement production is associated with the electricity costs. The biggest cost item is the consumption for the cement clinker grinding. It is known that disperse characteristics of cements, such as fineness of grinding, specific surface, coarseness of grading, largely determine their hydraulic properties, and for expanding cements - the deformation ones. In the paper, the issues of electric power consumption were considered when grinding extender expanders: aluminous slag, sulfoaluminate, sulfoferrite and sulfoalumoferrite clinkers.

Keywords: Expansive Cement, Grindability, Alumina Slag, Sulfoaluminate Clinker, Sulfoferrite Clinker, Sulfoalumoferrite Clinker.

1. Introduction

Concrete and reinforced-concrete products with drying and hardening are reduced in volume and their shrinkage occurs. With prolonged shrinkage action and the presence of hard obstacles to volume reduction, for example, reinforcement or aggregate, holding-down gears, high tensile stresses arise in the cement stone, which can lead to the formation of cracks and destruction of concrete [1,2].

Reduction in shrinkage is usually achieved by constructive methods: increase in the number of reinforcement, breakdown of structures into separate blocks, increasing the frequency of shrinkage joints and other ways [3]. As a rule, all these measures increase construction costs and can shorten the life of structures. Scientists and builders have always tried to find ways to compensate for shrinkage or to receive a positive expansion, so that it forever gives the right tension [4-6].

One way to reduce shrinkage is to use expanding cements [7]. At present, many different types of expanding cements are known [8]. The most common way to produce expanding cements is joint or separate grinding, followed by mixing of Portland cement clinker, gypsum and special additive [9,10].

Expanding cement upon hardening causes an increase in the volume of the cement stone, its compaction and self-stress. It is used in the construction of residential and industrial buildings, in the construction of chemical facilities, treatment facilities, as well as in the construction of tunnels and underground stations [11]. Among such additives, aluminous slag, sulfoaluminate, sulfoferrite and sulfoalumoferrite clinkers were widely used [12-15].

Recently, there has been a steady increase in electricity tariffs and much attention has been paid to the energy and natural resource conservation. Studies were carried out to determine the specific consumption of electric power required on grinding of the expanders. The aim of the work was to study the grindability of expanders to various dispersities and to determining the specific energy consumption spent on grinding. The aim of the work was to study the grindability of expanders to various dispersities and to determining the specific energy consumption spent on grinding.

2. Material and Methods

Portland cement clinker (PCC), aluminous slag (AS), sulfoaluminate (SAC), sulfoferrite (SFC) and sulfoalumoferrite (SAFC) clinkers were used as starting materials in the work. The chemical composition and loss of ignition (L.O.I) of the materials is shown in Table 1.

Table 1: The chemical composition of the materials

<table>
<thead>
<tr>
<th></th>
<th>Portland cement clinker</th>
<th>Aluminous slag</th>
<th>Sulfoaluminate clinker</th>
<th>Sulfoferrite clinker</th>
<th>Sulfoalumoferrite clinker</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>20.1</td>
<td>10.5</td>
<td>12.77</td>
<td>12.23</td>
<td>14.76</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>4.56</td>
<td>47</td>
<td>14.73</td>
<td>3.09</td>
<td>10.87</td>
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<tr>
<td>Fe₂O₃</td>
<td>8.72</td>
<td>0.8</td>
<td>3.2</td>
<td>23.79</td>
<td>13.78</td>
</tr>
<tr>
<td>CaO</td>
<td>62.75</td>
<td>39.35</td>
<td>51.45</td>
<td>51.83</td>
<td>56.39</td>
</tr>
<tr>
<td>MgO</td>
<td>1.99</td>
<td>-</td>
<td>1.76</td>
<td>1.92</td>
<td>2.04</td>
</tr>
<tr>
<td>SO₃</td>
<td>0.57</td>
<td>-</td>
<td>10.45</td>
<td>5.19</td>
<td>2.39</td>
</tr>
<tr>
<td>R₂O₃</td>
<td>1.58</td>
<td>0.12</td>
<td>2.7</td>
<td>0.11</td>
<td>0.51</td>
</tr>
<tr>
<td>L.O.I</td>
<td>0.92</td>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The components were ground in a laboratory mill to a specific surface area of 300 m²/kg and 400 m²/kg. Additives with a different specific surface area were then mixed with Portland cement and their deformation characteristics were studied. The grindability of materials is characterized by the functional dependence of the fineness of the grinding on the specific energy consumption spent on grinding. The specific energy consumption was calculated using the formula (1):
Definition 1.1: The specific energy consumption, where $E_{ef}$ – specific energy consumption (effective) expended during grinding for $n$ rounds of the mill, kW·h/t; $n$ is the number of rounds of the mill, counting from the beginning of grinding; $P$ is the weight of the loaded material, kg; $48$ – rotational speed of the mill rpm; $0.28$ – is effective power of grinding bodies developed in one compartment of the mill at loading 55.0 kg of grinding bodies and material breakdown, kW.

Specific production was calculated with the formula (2):

$$b = \frac{1000}{E_{ef}}$$  \hspace{1cm} (2)

Definition 1.2: Specific production, kg/h/kW

The processed data on the determination of grindability are presented in Table 2.

3. Results and discussion

From the presented results, the most energy-intensive one is the grinding of the sulfoaluminoferritic clinker. So, to achieve a specific surface area of $S_{sp}=300 \text{ m}^2/\text{kg}$, 42 kW·h/t is required for the grinding of the sulfoaluminoferritic clinker, 37.3 kW·h/t for the sulfoferritic clinker, 32.7 kW·h/t for the Portland cement clinker.

The most easily milled ones are aluminous slag and sulfoaluminate clinkers, to achieve $S_{sp}=300 \text{ m}^2/\text{kg}$, upon grinding they require 23.3 kW·h/t and 9.3 kW·h/t, respectively.

To achieve a specific surface area of the studied materials of 400 $\text{m}^2/\text{kg}$, specific energy consumption was 70 kW·h/t for the sulfoaluminoferritic clinker, 60.7 kW·h/t for the sulfoferritic clinker, 60.7 kW·h/t for Portland cement clinker, 37.3 kW·h/t for the aluminous slag 18.7 kW·h/t for the sulfoaluminate clinker. The graphical characteristic of grindability of the materials is shown in Fig.1 and Fig.2.

![Characteristics of grindability](image)

**Fig. 1:** Characteristic of grindability of the portland cement clinker, aluminous slag and sulfoaluminate clinker
Fig. 2: Characteristic of grindability of the portland cement clinker, sulfoferrite and sulfoalumoferrite clinkers

4. Conclusion

It is seen from the above dependences that the fineness of the grinding of materials is different under identical grinding conditions, and this difference is primarily due to the crystalline structure of the minerals and their hardness.

Most of the time and electricity to achieve a specific surface of 300 m²/kg and 400 m²/kg is spent at the grinding of the sulfoaluminoferrite clinker, it is 90 minutes (1.5 hours) and 150 minutes (2.5 hours), respectively.

According to the results of the studies (Table. 3), the deformation characteristics and the construction and technical properties of cements based on aluminous slag and sulfoaluminate clinkers are good, and based on studies of electric energy costs for grinding, it is possible to recommend the use of these additives for the production of expanding cements.

Table 3: Expansion and strength of cements

<table>
<thead>
<tr>
<th>№</th>
<th>Material</th>
<th>Specific surface area of expansive additives, m²/kg</th>
<th>Expansion, %</th>
<th>Bending strength, MPa</th>
<th>Compressive strength, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PPC+AS +gypsum</td>
<td>420</td>
<td>0.23</td>
<td>7.06</td>
<td>64.82</td>
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<tr>
<td>2</td>
<td>PPC+SAC +gypsum</td>
<td>398</td>
<td>0.25</td>
<td>6.82</td>
<td>66.05</td>
</tr>
<tr>
<td>3</td>
<td>PPC+SFC +gypsum</td>
<td>404</td>
<td>0.12</td>
<td>5.16</td>
<td>43.75</td>
</tr>
<tr>
<td>4</td>
<td>PPC+SAFC +gypsum</td>
<td>400</td>
<td>0.15</td>
<td>5.39</td>
<td>56.55</td>
</tr>
</tbody>
</table>

References