Influence of Sodium Oxide on Brightness Coefficient of Portland Cement Clinker

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Abstract. The paper is devoted to the possibility of adjusting the reflection factor of portland cement clinker. For this purpose, Na_2CO_3 is introduced into the slurry of CJSC Belgorod Cement Plant. The influence of Na_2O on brightness coefficient of the crushed clinker is established at a burning temperature of 1250–1300 °C. With the increase of Na_2O concentration up to 1–2% the brightness coefficient is reduced and the increase of Na_2O in the range of 3.5–7% leads to sharp increase of the reflection factor and CaO_{free} content.

Keywords: Sodium oxide · Brightness coefficient · White cement · Free calcium oxide

1 Introduction

Modern rotary furnaces of cement industry are characterized by accumulation and circulation of alkali salts in the furnace system (Luginina 2002). As a result, the R_2O content of furnace charge may reach 3.5% before the sintering zone, and in some plants this value may even reach 10%. The formation of calcium aluminate ferrite is not observed in furnace charges of alumina industry characterized by high Na_2O content due to the formation of aluminates and sodium ferrites (Lisiyenko 2004). Hence, as may be expected, the accumulation and circulation of alkali salts will lead to the situation that occurs in furnaces of alumina industry.

Raw mixes from analytical reagents used to obtain C_4AF are characterized by the formation of sodium compounds instead of calcium compounds (Kovalyov 2015). It will allow obtaining a clinker of lighter shade.

Thus, the purpose of this study is to determine the possibility of adjusting the brightness coefficient of portland cement by introducing sodium oxide into the raw mix.

2 Methods and Approaches

The dried slurry of CJSC Belgorod Cement Plant with the following modular characteristics: $\text{KH} = 0.91$; $n = 2.23$; $p = 1.29$ was used as a raw mix (Table 1).

Table 1. Chemical composition of slurry of CJSC Belgorod Cement Plant, %

<i>Losses on ignition</i>	<i>SiO₂</i>	<i>Al₂O₃</i>	<i>Fe₂O₃</i>	<i>CaO</i>	<i>MgO</i>	<i>K₂O</i>	<i>Na₂O</i>	<i>SO₃</i>	<i>Other</i>
34.8	14.23	3.59	2.78	43.12	0.6	0.4	0.11	0.09	0.37

Sodium carbonate of CH classification was introduced into the raw mix in the amount of 0.5; 1; 2; 3.5; 5; 7% of Na₂O in equivalent of ignited basis. Tablets weighing 2 g were formed from obtained mix under manual pressure. In order to avoid Na₂O volatilization during roasting, the samples were covered with a platinum cup. Roasting of samples was carried out in a laboratory furnace with isothermal time of 20 min. The heating rate of the furnace made 10 °C/min.

The influence of alkali salts on the formation of aluminate-ferrite phase was estimated according to the content of free calcium oxide and the brightness coefficient of samples. The CaO_{free} content in a clinker was defined through ethyl-glycerate method (Butt and Timashev 1973). The whiteness (brightness coefficient) of a clinker was defined via FB-2 reflection meter on a reference polished barium sulfate plate.

3 Results and Discussion

The compositions burned at 1250 and 1300 °C were analyzed. The roasting temperature was chosen based on the following: at given temperatures the formation of belite was complete, and the synthesis of alite had not started yet. As a result, the formation of silicate phases would not change the content of free calcium oxide.

At a temperature of 1250 °C (Fig. 1) at the initial stage (up to 1% Na₂O) the content of free calcium oxide is reduced alongside with the brightness coefficient (BC). The brightness coefficient almost does not change with Na₂O concentration in the range of 1–3.5% and the content of free calcium oxide. With the introduction of over 3.5% of Na₂O the CaO_{free} content and the brightness coefficient sharply increase.

Fig. 1. Influences of Na₂O on brightness coefficient and content of free calcium oxide at 1250 °C roasting temperature.

At a roasting temperature of 1300 °C (Fig. 2) a similar situation is observed. With the amount of introduced Na_2O up to 1–2% the considered characteristics are reduced. Sharp increase of reflection factor and CaO_{free} content was also observed in the range of 3.5–7% of Na_2O .

Fig. 2. Influence of Na_2O on reflection factor and content of free calcium oxide at 1300 °C roasting temperature.

The relatively low content of free calcium oxide without alite formation may be caused by the formation of intermediate phases, for example carbonate spurrite. The presence of Na_2CO_3 in the system fosters its formation. Hence, the increase of Na_2O content at the initial stage leads to CaO_{free} decrease.

The sharp increase of free calcium oxide content starting from Na_2O concentration of approximately 3.5% confirms the formation of ferrites or sodium aluminates instead of calcium aluminate ferrites in clinker systems, since such interaction results in the emission of additional amounts of calcium oxide and may be presented by the following reactions:

The change dependence of brightness coefficient within samples on Na_2O content in a clinker correlates with the change dependence of free calcium oxide content. This may be explained by the fact that CaO_{free} crystals are white. Therefore, the increase or reduction of its content leads to the corresponding change of the brightness coefficient of a clinker. Based on above conclusions, the sharp increase of the brightness coefficient with the increase in Na_2O concentration of over 3.5% may also be caused by the complexity of aluminate-ferrite phase. This phase is the most colored part of a clinker (Zubekhin et al. 2004). Hence, the change of its composition and quantity resulting from the formation of aluminates and sodium ferrites will be characterized by the corresponding change of the brightness coefficient of a clinker.

4 Conclusions

The introduction of up to 2–3.5% of Na_2O leads to the decrease in the brightness coefficient of samples due to the reduction of free calcium oxide content. Apparently, this is caused by the formation of intermediate phases – carbonate spurrite.

The Na_2O content of over 3.5% increases the brightness coefficient of samples. This is caused by the formation of aluminates and sodium ferrites instead of aluminates and calcium aluminate ferrites.

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