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Communication

Influence of heating rate on the burning of cement clinker

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Abstract

The effects of heating rate on the burning of cement raw mix are analyzed in view experiments. Raw mix is produced from limestone, loam, and sand, then granulated and burnt in the gradient furnace to produce clinker. To investigate the dependence of burning of raw mix on heating rate, two different heating regimes were applied. The first heating regime was final temperature 1450 °C, burning duration 145 min, and rates of heating 29.5 and 3.85 K/min. The second heating regime was final temperature 1410°C, duration 112 min, and rates of heating 36.4 and 5.3 K/min. As a result of microscopic investigations, it was noted that there were no significant differences between two clinker samples in terms of the sizes, forms, and distributions of free CaO, alite, and belite crystals. The amount of free CaO is the most important criterion for the burning of raw mix using a definite heating regime. Although there is a lower temperature and shorter burning duration, 2.09% free CaO is found in the clinker sample because of the high burning rate. It has been concluded that the clinker can be burnt at a lower temperature and for a shorter time with a high heating rate.

Keywords: Clinker; Thermal treatment; Kinetics; CaO

Efforts to reduce the burning temperature in practical burning processes are important. Weak burnt clinker was formed by lowering the burning temperature or burning time. These types of clinkers have high free CaO but the same amount of other constituents as in conventional Portland clinkers. According to previous research [1], hydraulic reactions do not change relative to commonly burnt clinkers; actually they are better. A high heating rate encourages the sintering of cement raw mix, because CaO and other oxides show high activity due to the fault recrystallization. High activity provides fast formation of clinker phases below 1000°C and after the first liquid appears [2]. The reason for weak bonding of CaO in formation of clinker phase is the decreasing solubility of pieces in clinker solution caused by slow heating. This was explained by the decrease in structural defect in CaO and the formation of relatively large C_2S crystals while in solid-state reactions [3]. According to the research of plant conditions, a higher heating rate was observed on the surface of burnt grain at 0.92 rpm furnace speed as compared to 1.33 rpm oven speed [4]. The aim of this study was to produce favorable clinkers by lowering the burning temperature and burning time with rapid heating.

1. Experimental

Raw mix is composed of limestone, loam, and sand. Ten percent water was added to the raw mix (lime saturation factor: 93.27, silica ratio: 2.85, alumina-iron ratio: 2.10, +90 μm: 10.8%), then the raw mix was granulated on a laboratory granulation plate. After drying, the granules were weighed on a platinum plate and burnt in a furnace according to heating regime HR-1 (Fig. 1) for forming clinker (K-1). Heating regime HR-2 was applied for the second burning operation (K-2). To describe the burnability, the amount of free CaO in the clinker samples was determined by the Schlaepfer-Bukowsky titration method, relative alite amounts were compared by X-ray diffraction method, and internal structure was observed using a polarized microscope.

2. Results and discussion

Free CaO amounts determined by titration given on Table 1. The reason for higher free CaO amount in K-2 sample can be lower burning temperature and shorter burning time. Although the lower temperature and shorter burning time as shown on HR-2 applied to the K-2 sample, the amount of free CaO was found to be 2.09% due to the high heating gradient.

To compare the alite amounts in clinker samples K-1 and K-2, nonoverlapped alite peaks were examined, but absolute alite amounts cannot be determined from here. Higher

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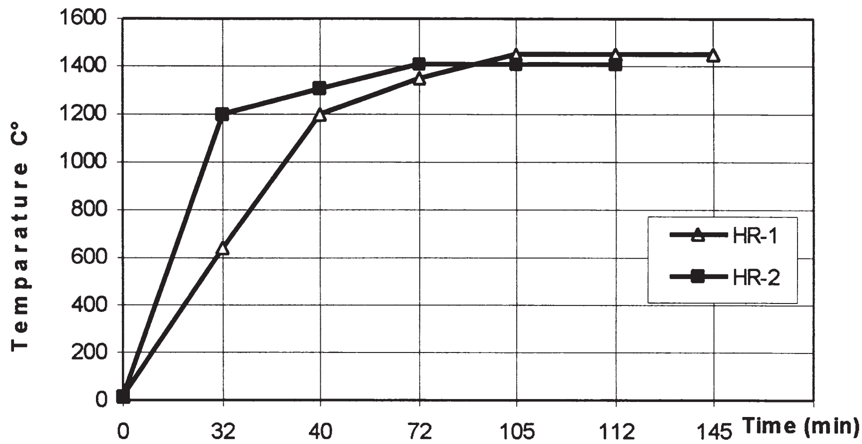

Fig. 1. Heating regimes HR-1 and HR-2.

alite peaks were read in clinker sample K-1. Higher alite and lower free CaO content of clinker sample K-1 are shown in Fig. 2. Due to the high burning temperature and longer burning time, better CaO bonding occurred. Nonuniform pore structures are shown in Figs. 3 and 4. Some pores are connected with each other. The size of the closed pores is nearly 30 to 60 μm in both samples. The pore structures of the two samples are the same, and the shape changed from round to elongated. The longest pore size is 1100 μm in sample K-1 and 1400 μm in sample K-2. Figs. 5 and 6 show grape-shaped free CaO. Free CaO is in cluster form and in individual forms in both samples, with no size difference. The size of the CaO crystals is nearly 10 to 60 μm. The size of the free CaO nest is about 300 μm. The reason for the nest cab may be the insufficient grinding of calsite grains and improper homogenization of raw mix. Black regions of the picture are unfilled pores with synthetic resin. Due to the oxidation effect of air, a Ca $(OH)_2$ layer occurs on the CaO crystals, which gives different reflections. The sizes of the alite crystals are the same in both clinker samples (Figs. 7 and 8). The sizes of the crystals are very changeable and are approximately 8 to 50 μm. Fig. 7 shows polygonal alite crystals with belite knots, which are belite crystal remainders participating in alite formation. Belites were formed at the surroundings of the pores filled with synthetic resin. The size of the belite crystals are different and are approximately 15 and 60 μm (Figs. 9 and 10). The reason for formation of big belite crystals may be crystallization col-

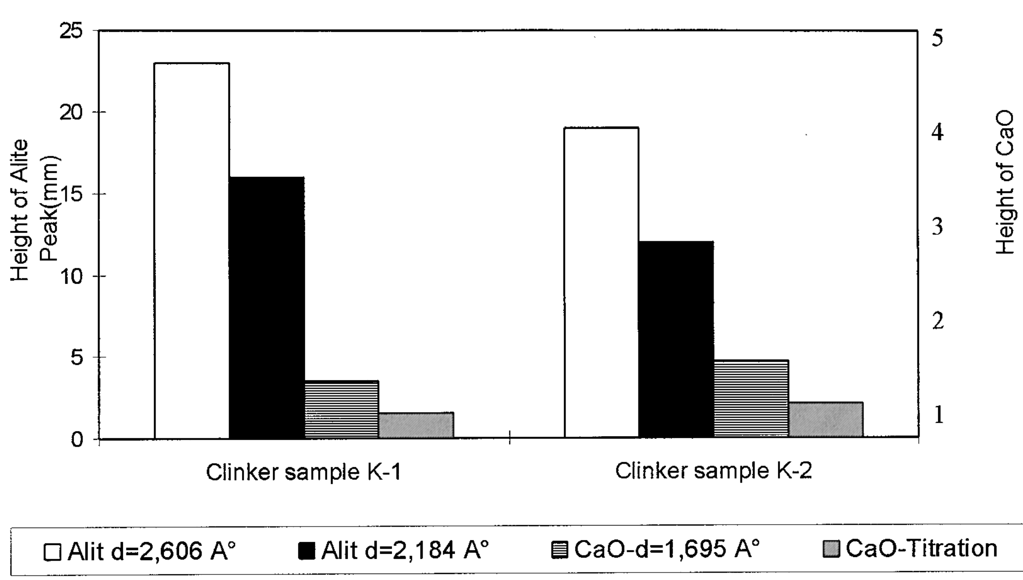

Fig. 2. Height of alite and free CaO peaks, free CaO amounts of clinker samples.

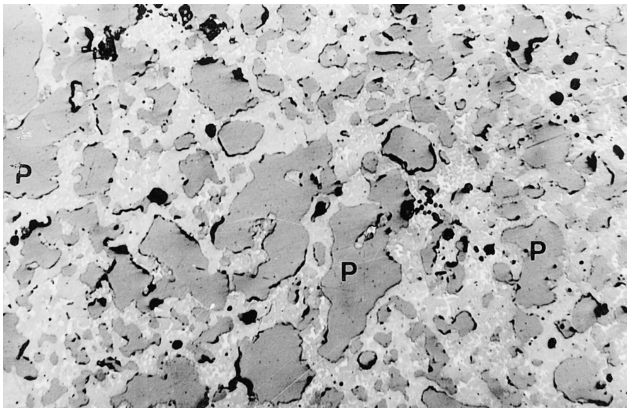

Fig. 3. Clinker sample K-1. P, pore.

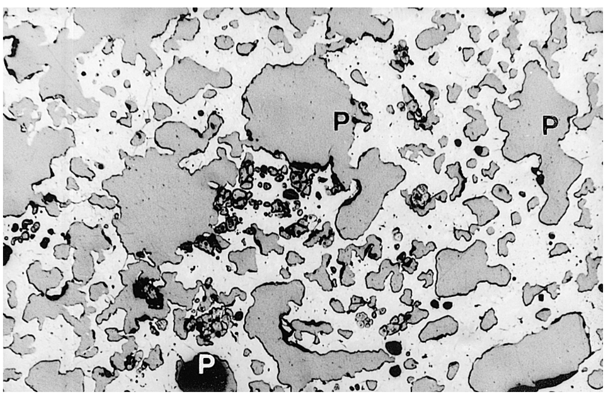

Fig. 4. Clinker sample K-2. P, pore.

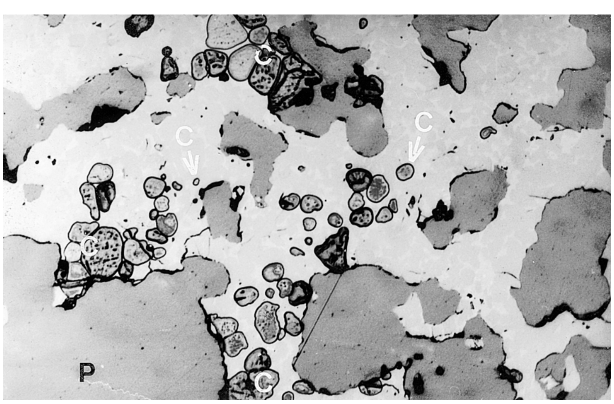

Fig. 5. Clinker sample K-1. C, free CaO; P, pore.

Table 1
Free CaO amounts in clinker samples

Clinker sample	According to titration (%)
K-1	1.56
K-2	2.09

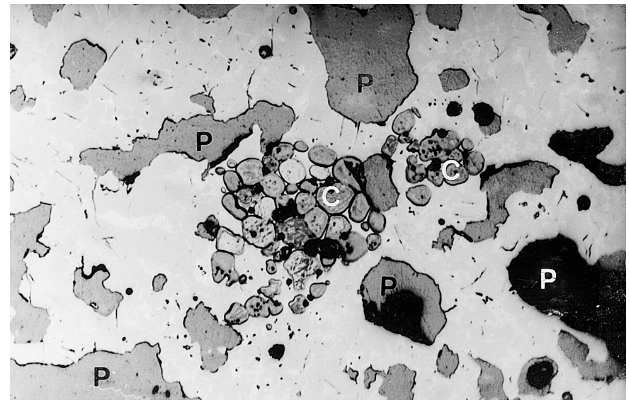

Fig. 6. Clinker sample K-2. C, free CaO; P, pore.

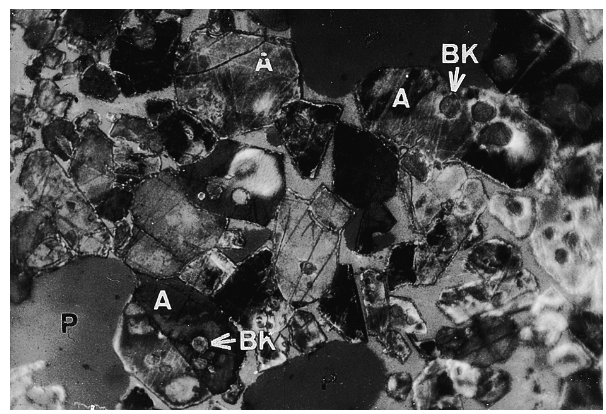

Fig. 7. Clinker sample K-1. A, alite crystals; BK, belite knots; P, pore.

Fig. 8. Clinker sample K-2.

lected below the alite formation temperature. There are no obvious differences in pore and cyrstal shape, size, and distribution between the two clinker samples.

3. Conclusions

The most important criterion of the burnability of raw mix within a certain heating regime is the amount of free

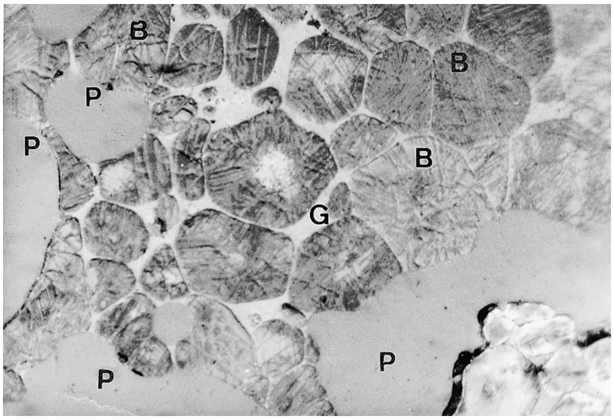

Fig. 9. Clinker sample K-1. B, belite; G, matrix; P, pore.

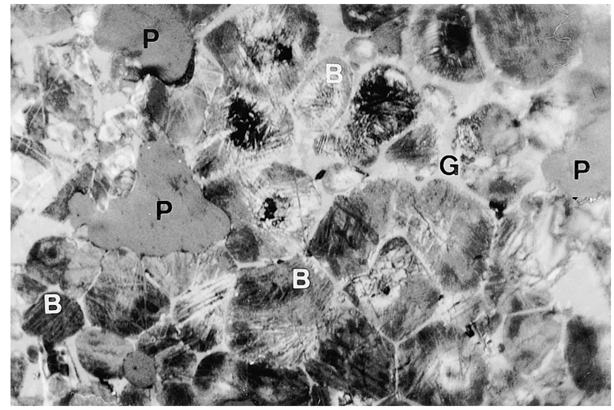

Fig. 10. Clinker sample K-2. B, belite; G, matrix; P, pore.

CaO. The free CaO content of clinker sample K-2, which was heated more rapidly and sintered at a lower burning temperature and shorter burning time, is 2.09%. According to the results of X-ray diffraction, the alite peaks of K-2 sample are shorter. Microscopic investigation of the two types of clinker samples show that there are no obvious differences in pore and crystal shape, size, and distribution between the two clinker samples. According to all investigations, cement raw mix can be burnt using the more economic heating regime HR-2.

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