

# Study on the Easily Grinding Portland Cement Clinker

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**Abstract** The easily grinding Portland cement clinker has been prepared by increasing the content of  $C_3S$  in the clinker and adding the mineralizer to the raw mix. The mineral composition, grinding characteristic and the physical property of the easily grinding Portland cement clinker were researched. The easily grinding Portland cement clinker could be prepared at the temperature  $\leq 1400$  , its mineral composition is similar to that of the Portland cement clinker. There is a characteristic that the  $C_3S$  content of the easily Portland grinding cement clinker is up to 73.8wt% based on the whole mineral composition. On the same test condition, it takes for 4.5 min when the specific surface area of the easily grinding Portland cement clinker attains to  $320 \text{ m}^2/\text{kg}$  and the ordinary Portland cement clinker needs to be ground for 8 min. The easily grinding Portland cement clinker has the characteristic of short setting time and high early compressive strength. The 3-day and 28-day compressive strength of the easily grinding Portland cement may attain to 37MPa and 60MPa, respectively.

**Keywords:** Portland cement clinker; Easily grinding; Clinker compositions; Physical property.

## 1. Introduction

The grinding property of Portland cement clinker relates to two problems: (1) the energy consumption of cement production and (2) the physical property of cement. It is a significant percentage of the total cost of cement. How to improve economically and effectively fineness of Portland cement clinker has been a research project for many years. The grinding aids is used usually in order to improve the production capability of the mill and save the energy consumption during the grinding process of cement. There is another measure that transforming the mill structure could also increase the production capability on the condition of the same energy consumption. It is difficult that the above-mentioned measures are adopted in practice for cement plants because there are some problems,

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such as the performance of grinding aids and the cost of transforming the structure of the mill.

The grindability of cement clinker depends on its chemistry and on the conditions it experiences in burning.[1,2,3,4,5,6] It is known that the clinker minerals of  $C_3S$ ,  $C_2S$ ,  $C_3A$  and  $C_4AF$  have different brittleness index coefficient. The values have been calculated:  $C_3S$ , 4.7;  $C_2S$ , 2.0;  $C_3A$ , 2.9 and  $C_4AF$ .2.0. [7] The easily grinding Portland cement clinker may be prepared through the research on the clinker composition and structure according to the related research results. The possibility of preparing easily grinding Portland cement clinker has been discussed by adding the calcium sulphate to the raw mix. [8] In this paper, the easily grinding Portland cement clinker has been prepared by increasing the content of  $C_3S$  in the clinker and adding the mineralizer to the raw mix. The composition, physical property and the mineral optical characteristic of the easily grinding Portland cement clinker are reported.

## 2. Experiment and test

### 2.1. Raw materials and raw mix

Table 1 The chemical composition and the fineness of the raw materials limestone and clay (wt.%)

Sample	Loss	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	The residue of 80μm sieve
Limestone	42.72	1.89	0.52	0.27	54.08	0.54	9.03 %
clay	5.00	66.37	14.90	5.84	2.57	2.23	4.63 %

Table 2 The chemical compositions of the raw mix EC and OC

No.	Raw mix (wt.%)					Chemical composition (wt.%)					
	Lime-stone	clay	Fe <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	Loss	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	Σ
EC	79.6	18.1	1.8	0.5	34.94	13.52	3.59	3.07	43.5	0.83	99.5
OC	78.3	20.0	1.8	0	34.44	14.73	3.38	3.13	42.8	0.87	99.5

The chemical compositions of limestone and clay were shown in the table 1. Raw mix is composed of limestone, clay, Fe<sub>2</sub>O<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub> and the mineralizer. Both Fe<sub>2</sub>O<sub>3</sub> and Al<sub>2</sub>O<sub>3</sub> are the chemical reagents. The composition of raw mix is listed in the table 2. In order to state clearly the performance of easily grinding cement clinker, the ordinary Portland cement clinker is preference as the control. The composition of ordinary Portland cement clinker is designed on the basis of the general practical composition of industrial production in China. In the table 2, No. EC

represents the easily grinding cement clinker and the No. OC is the ordinary Portland cement clinker.

## 2.2. Experimental methods

Free-CaO determination: The burning tests were carried out in pellets (weight: 5.0g, d: 20mm, h: 6mm) which were thermally treated for 30 minutes at 4 different temperatures 1300, 1350, 1380 and 1400 . After sintering the samples were air cooled, ground and analyzed by the ethylenoglycol method in order to determine the free-CaO content.

The larger pellets (d: 130g, d: 80mm, h: 13mm) is prepared in order to make the physical test of cement clinker. The burning condition is at the temperature 1400 for 120 min. The burned samples were cooled in air. The sample is ground together with gypsum in the ball mill and SO<sub>3</sub> content of the ground sample is 2.1%.

Grinding property of clinker: The clinker was crushed to the particle about  $\phi 3$  mm in size. The clinker particle (weight: 50g) was ground at the vibration mill for different time. The relationship curve of specific surface area with the grinding time is drawn.

Test of physical property: The motor strength, specific surface area (Blaine), water requirement and setting time were tested according to the GB177, GB207 and GB1346, respectively.

Mineralogical phases and chemical composition: X-ray diffraction (XRD) was used in order to identify the mineralogical phases of clinker. The chemical composition of clinker was analyzed by the related chemical analysis methods. The optical property of the mineral was examined with the optical microscope.

## 3. Results and Discussion

### 3.1. Designed composition of clinker

Table 3 The designed modulus and the phase compositions of the clinker EC and OC

No	Modulus			Potential compound compositions (wt.%)			
	KH	SM	IM	C <sub>3</sub> S	C <sub>2</sub> S	C <sub>3</sub> A	C <sub>4</sub> AF
EC	0.965	2.03	1.17	70.6	6.3	6.6	14.0
OC	0.877	2.26	1.08	53.9	23.8	5.6	14.5

The designed modulus and the phase composition of the clinker EC and OC are shown in the table 3.

From the table 3, the designed  $C_3S$  content in the EC clinker is equal to 70.6% and  $C_2S$  content is 6.3%. However, the  $C_3S$  content in the clinker OC is 53.9% and  $C_2S$  is 23.8%. The content of the mineral  $C_3A$  and  $C_4AF$  is approximately equal.

### 3.2. Chemical analysis results of the clinker EC

Table 4 is the practical chemical compositions and the compound content of the clinker EC. According to the chemical compositions of the clinker, the  $C_3S$  content (calculated with the method of the R.H.Bouge) reaches to 73.8% in the clinker and the mineral  $C_2S$  is 1.2%. The content of the mineral  $C_3A$  and  $C_4AF$  is approximately equal to the designed content (shown in the table 3).

Table 4 The chemical compositions and the compound content of the clinker EC

No.	Chemical compositions (wt.%)					Compound content (wt.%)					
	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	Σ	C <sub>3</sub> S	C <sub>2</sub> S	C <sub>3</sub> A	C <sub>4</sub> AF	Σ
EC	19.79	5.26	4.74	65.45	1.86	97.1	73.8	1.2	5.9	14.4	95.3

### 3.3. Free –CaO content of the clinker EC

Table 5 Free-CaO content of the clinker EC at the different temperature (wt.%)

Temp.	1300	1350	1380	1400	The burning temp. of the f-CaO content ≤2.0%
EC	3.54	1.92	1.62	1.17	≤1350

Table 5 showed the free-CaO content of the clinker EC burned at the 4 different temperatures 1300 , 1350 , 1380 and 1400 . Although the  $C_3S$  content attains to 73.8% in the EC clinker, the free-CaO content in the EC clinker burned at the temperature 1350 is already less than 2% because of the addition of the mineralizer. At the temperature 1400 , the free-CaO content of the burned clinker is 1.17%. It is stated that the EC clinker could be prepared at the temperature less than 1400 .

### 3.4. Grinding Characteristic and the Physical Property of the Clinker EC

### 3.4.1 Grinding Characteristic

Fig.1 showed the relationship between the specific surface area and grinding time of the clinker EC and OC.

It will take for 4.5 min when the specific surface area of the clinker EC attains to 322.7 m<sup>2</sup>/kg. However, after the clinker OC is ground for 8 min its specific surface area reaches only to 325 m<sup>2</sup>/kg. It is noted that the grinding time of the clinker EC will decrease 3.5 min compared with the clinker OC on condition that the specific surface area of two clinkers is ground to 320 m<sup>2</sup>/kg.

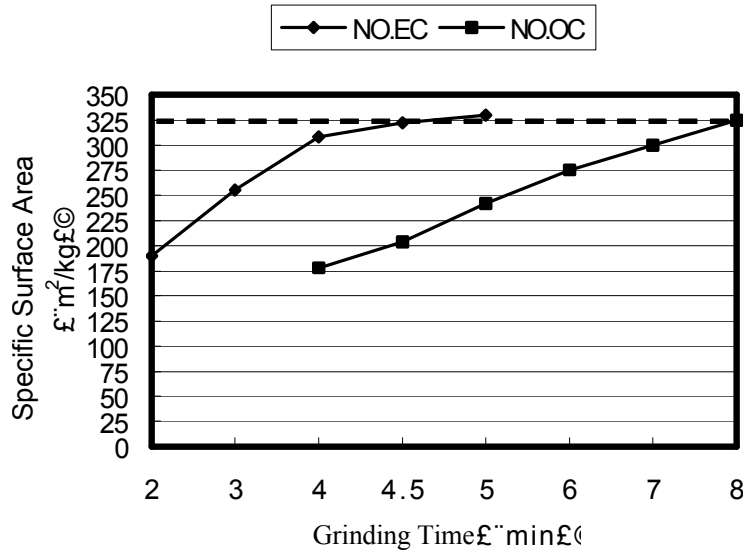


Fig.1 Relationship between specific surface area and grinding time of the clinker EC and OC

### 3.4.2 Physical Property

Table 6 The physical property of the clinker EC and OC

No.	Specific surface area (m <sup>2</sup> /kg)	Normal consistency (%)	Setting Time (h:min)		Flexural strength MPa		Compressive strength MPa	
			initial	final	3d	28d	3d	28d
EC	330	22	2 05	4 15	5.7	8.0	37.0	60.5
OC	325	25	3 50	5 05	4.1	8.2	23.6	61.1

The physical property of the clinker EC and OC is shown in the table 6. It could be seen that the setting time of the clinker EC is shorter than that of the clinker OC. The 3-day compressive strength of the clinker EC is more than that of the clinker OC. The 3-day compressive strength of the clinker EC increases 13.4MPa compared with that of the clinker OC. The 28-day compressive strength is similar for two clinkers. It is concluded that

the clinker EC has the characteristic of short setting time and high early strength.

### 3.5. XRD test

Fig.2 is the XRD patterns of the clinker EC and OC. It is stated from fig.2 that there is no difference in the XRD patterns of two clinkers. It is concluded that the crystal compound in the two clinkers is the same.

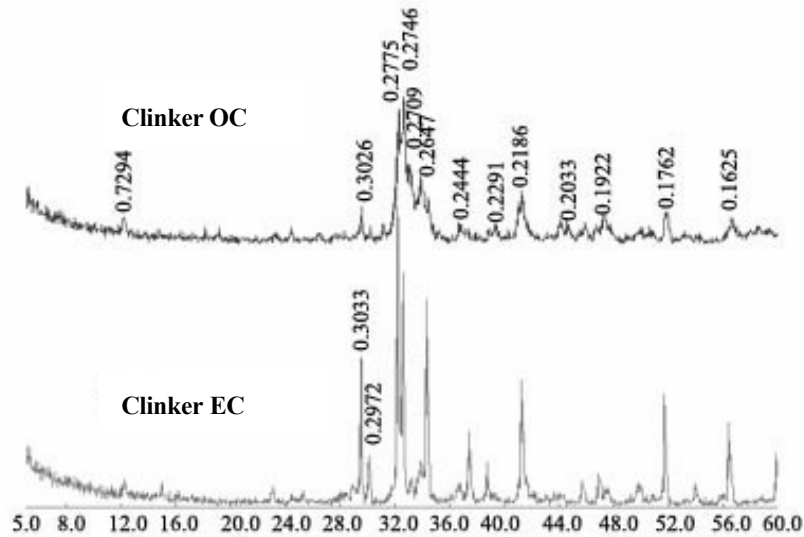


Fig.2 XRD patterns of the clinker EC and the clinker OC d: nm

### 3.6. Optical examination of the clinker EC

Fig. 3 is the optical photomicrographs of the clinker EC. According to optical examination of the clinker EC, the optical properties of the compounds in the clinker EC is respectively described as follows:

C<sub>3</sub>S (Alite): The mineral shows the pillar-like shape or sheet-like shape, in immersion of 3-40μm, generally 5-20μm. The crystal size is harmonious and the crystal has a distinct border. The edge of the crystal has the characteristic of the blunter. There exists C<sub>2</sub>S crystal around the crystal C<sub>3</sub>S and the white interstitial compounds in the inner part of the crystal C<sub>3</sub>S. (shown in the fig. 3(a)) However, The inner part of larger crystal C<sub>3</sub>S contains the crystal C<sub>2</sub>S.

C<sub>2</sub>S (Belite): The content of the crystal C<sub>2</sub>S is very low and is about 2-5%. It is difficult to find the individual C<sub>2</sub>S crystal. It exists together with other crystals.

Interstitial compounds: The content of the interstitial compounds is in the range of 18-21%.  $C_3A$  shows like the drop shape or the drop-line shape (shown in the fig.3(b)). The content of  $C_3A$  based on the amount of the interstitial compounds is up to 50%.

Free-CaO: Its immersion is in the range of 3~20 $\mu\text{m}$  (shown in the fig.3(b)). The content in the clinker is about 1%.

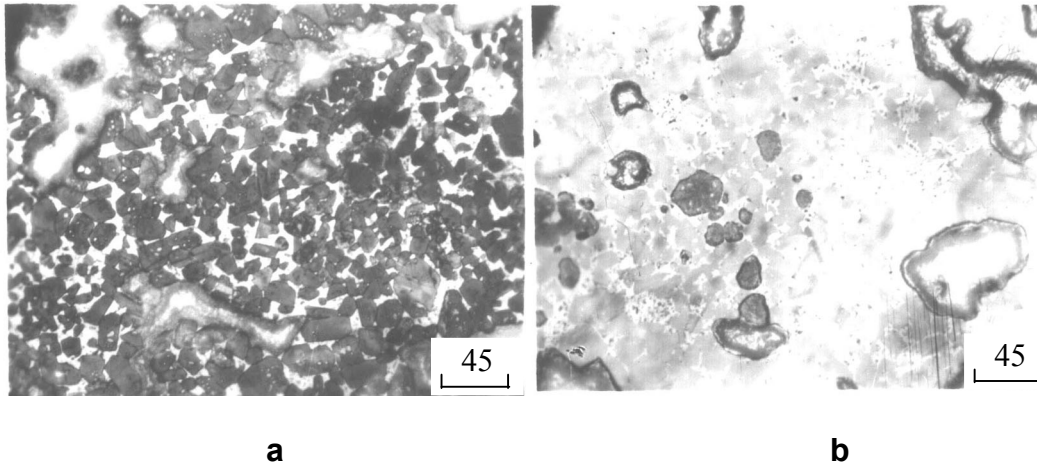


Fig.3 The optical photomicrographs of the clinker EC  $\times 200$

#### 4. Conclusions

The easily grinding Portland cement clinker is prepared at the burned temperature less than 1400 .  $C_3S$  content in the easily grinding Portland cement clinker reaches to 73.8% and the  $C_3S$  crystal shows the pillar-like shape and sheet-like shape. The phase compounds of the easily grinding Portland cement clinker is same to that of the Portland cement clinker.

After the easily grinding Portland cement clinker is ground for 4.5 min at the vibration mill, its specific surface area could attains to 320  $\text{m}^2/\text{kg}$ . However, it takes for 8 min for the Portland cement clinker to be ground to the same specific surface area.

The easily grinding Portland cement clinker has the characteristics of short setting time and high early strength. The compressive strength of the easily grinding Portland cement clinker cured for 3-day and 28-day could reach to 37MPa and 60MPa, respectively.

#### 5.References

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