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Regression Analysis on the Effect of Compressive Grinding of Cement Raw Materials and Clinker Granule

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Particle size of the cement raw materials is important not only in clinker burning but also in cement productivity. Model experiment was designed to investigate the effect of compressive grinding on cement raw materials and clinker granule. Compressive grinding was more efficient in reducing hard materials like quartz. Regression model was constructed to explain the effect of compressive grinding on the size reduction of cement raw materials and clinker.

Key words: Model experiment, Compressive, Grinding, Cement, Raw materials, Clinker

I. Introduction

Particle size of the ceramic materials is important not only in the physical and chemical reactions but also in the raw mill production.[1-6] Particle size of raw materials affects thc chemical reactions between raw materials.[7] There are so many parameters in the chemical reactions of raw materials in cement making process that are hard to be explained clearly and briefly.[8,9] Most well-known factors in the chemical reactions include the grain size of limestone, and the content and mineral state of siliceous raw materials.[8,9] Specially, siliceous sources like quartz and sand show relatively low grindability and reactivity in the chemical reactions, that is, clinkerization reactions. That is the reason that the overall reactivity of raw materials in the clinkerization reaction strongly depends on the particle size of siliceous source.

Compressive grinding has received much attention recently compared to the traditional grinding method by impact and attrition.[11-17] Compressive grinding is the system that feeds coarse materials into two rolls rotating in opposite directions and presses them by very high compressive stress as shown in Fig. 1. Major components in compressive grinding system are two grinding rolls and the drive motor system for two rolls, where one axis is fixed and the other axis is flexible to relieve the overloads during grinding. Compressive grinding system can be applied for several purposes depending on the applications such as pre-grinding and finish grinding in cement making process.

This grinding system has very bright future because compressive grinding has many advantages over traditional millings such as low noise level and electric costs. This research was intended to study the effect of compressive grinding on the size reduction of cement raw materials and clinker granule using newly designed model experiment. The effect of compressive grinding on the size reduction of cement raw materials and clinker granule was statistically analyzed using regression analysis. This approach is necessary to select the proper grinding system depending on materials and applications.

II. Experimental Procedure

Compressive strength tester was used in order to check the effect of compressive grinding on materials. Materials tested in this study are limestone and quartz as cement raw materials, and clinker granule. General chemical compositions of limestone and quartz, and clinker are shown in Table 1. Grinding effects were checked with the particles range between 13 and 20 mm. Compressive strength tester(Max. 300t) was used to apply pressure over the steel mold with 15 cm in diameter as shown in Fig. 2. The amount of materials pressed in the mold is fixed as 2.5 kg for all tests. Compressive pressure was determined after screening test and controlled into three levels: 72 ton, 108 ton, and 144 ton. Fig. 3 shows the flow chart of experimen-

Table 1. Chemical Compositions of Cement Raw Materials and Clinker Granule

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Ig. Loss
Limestone	4.0	1.2	0.5	49.3	2.4	0.35	0.02	41.7
Quartz	87.6	7.5	1.4	0.5	0.2	1.26	0.12	1.4
Clinker	21.7	6.5	3.0	64.7	3.2	0.7	0.04	0.0

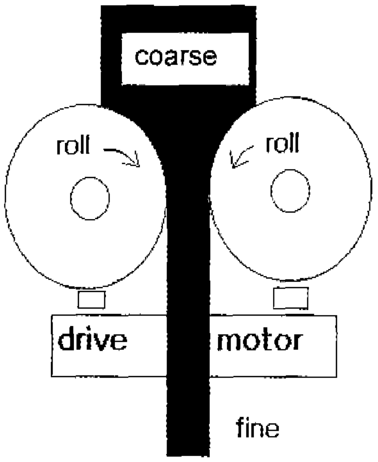

Fig. 1. Schematic diagram of grinding rolls.

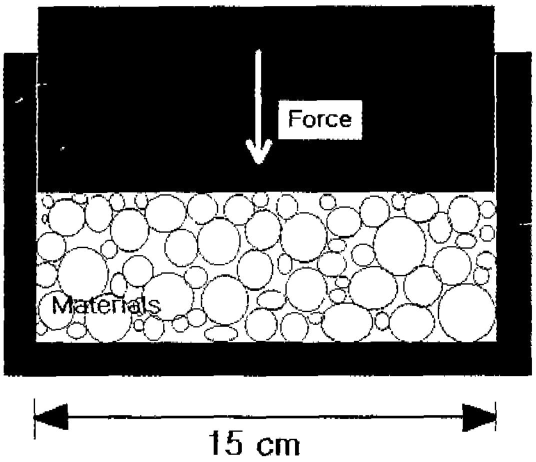

Fig. 2. Schematic diagram of model experiment of compressive grinding.

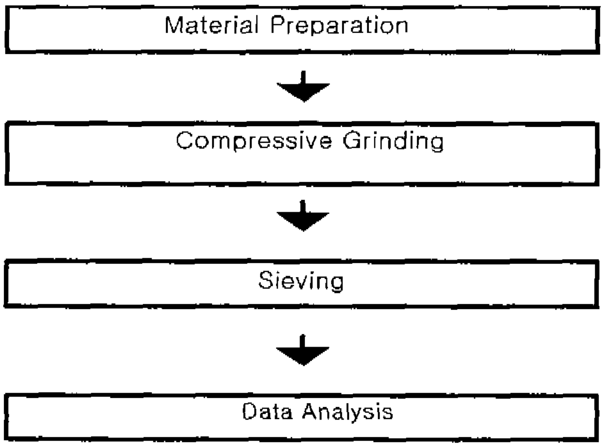

Fig. 3. Experimental procedure of compressive grinding effect on particle size reduction.

tal procedures, where raw materials and clinker granule were pressed by the compressive strength tester. Changes in particle size were measured by sieve analysis after compressive grinding. Results of sieve analysis were statistically analyzed by the regression method.[10]

III. Results and Discussion

Raw materials and clinker granule were pressed by the compressive strength tester at the various pressures as mentioned before. Particle sizes were measured by various sieves after compressive grinding, and the sieving results on the broken particles are summarized in Fig. 4-7: Fig. 4 for limestone, Fig. 5 for quartz, Fig. 6 for clinker, and Fig. 7 for cement raw materials and clinker granule at 144 ton. All materials used were prepared within the particle size range, 13~20 mm, for grinding test. Figs. 4-6 show the dramatic effect of compressive grinding on the size reduction of three kinds of materials at 72 ton, 108 ton, and 144 ton, where grinding effect gradually decreased with increasing applied pressure. This gradual decrease in grinding efficiency with increasing pressure is due to the space filling effect of the broken small particles into the interstices

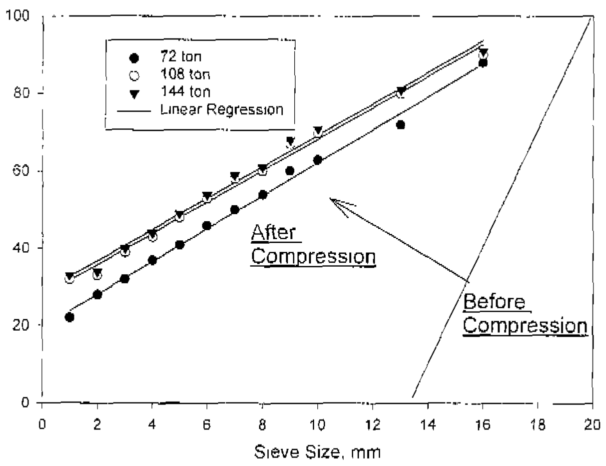

Fig. 4. Particle size distribution after compressive grinding on coarse limestone particles.

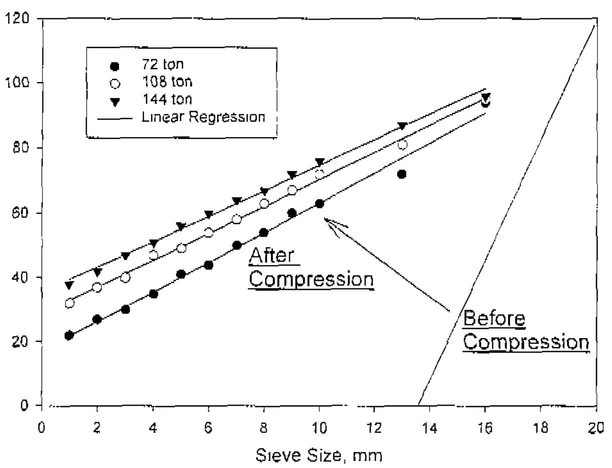

Fig. 5. Particle size distribution after compressive grinding on coarse quartz particles.

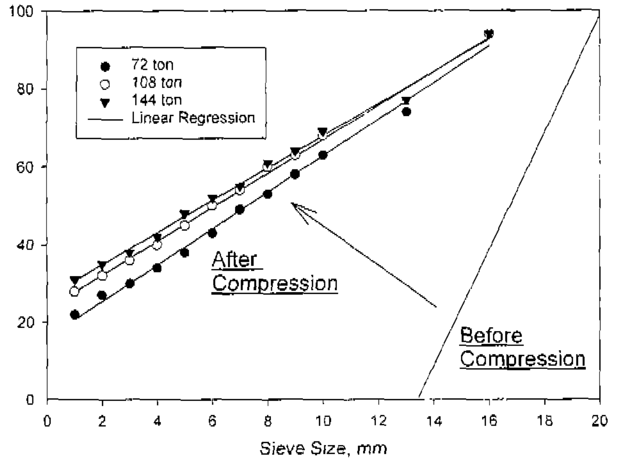

Fig. 6. Particle size distribution after compressive grinding on coarse clinker particles.

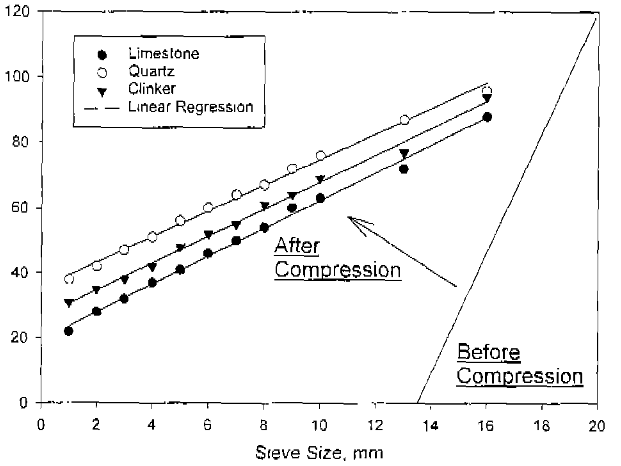

Fig. 7. Particle size distribution after compressive grinding at 144 ton.

between coarse particles. Fig. 7 shows the results of compressive grinding on three different materials after grinding test at the maximum load, where the particle size distributions of quartz, limestone, and clinker changed dramatically after grinding at the maximum load of 144 ton. The order of easiness in compressive grinding is quartz, limestone, and clinker as shown in Fig. 7. This order of easy grinding is different from the generally known order of easy grinding by ball milling. This is due to the fact that there is a basic difference in grinding mechanism. It is well known that materials with high hardness are weak in compressive pressure. Consequently, compressive grinding induces different grinding effect in the particle size distribution of different raw materials and clinker granule. Fig. 8 shows the regression coefficient b[0] with compressive pressure in the following regressional model:

Sieve Passing [%]=b[0]+Applied Pressure×b[1]

where b[0] is the intercept of the linear regression with y-axis in Figs. 4-7 and b[1] is the slope of the regression lines in Figs. 4-7.

All the regression lines in Figs. 4-7 showed very high correlation coefficients over 0.99. In above linear regression equation, the intercept b[0] shows the general level of particle sizes after compressive grinding and the slope b[1] shows the sensitivity of compressive grinding with applied pressure. In Fig. 8, quartz shows almost linear increase in b[0] value with applied pressure but limestone shows little increase in b[0] value at 140 Ton. Clinker shows intermediate behavior between limestone and quartz. This difference in b[0] value explains the difference in the effectiveness of compressive grinding over different kinds of materials.

In Fig. 9, b[1] values show the general decrease with applied pressure regardless of the kinds of materials, where particle grinding becomes less sensitive at higher pressure. Quartz and clinker showed similar decreases and limestone showed milder decreases. This means that quartz and clinker are more sensitive to applied pressure during the compressive grinding process than limestone. These regression coefficients, b[0] and b[1] in Fig. 8 and 9, are very useful in

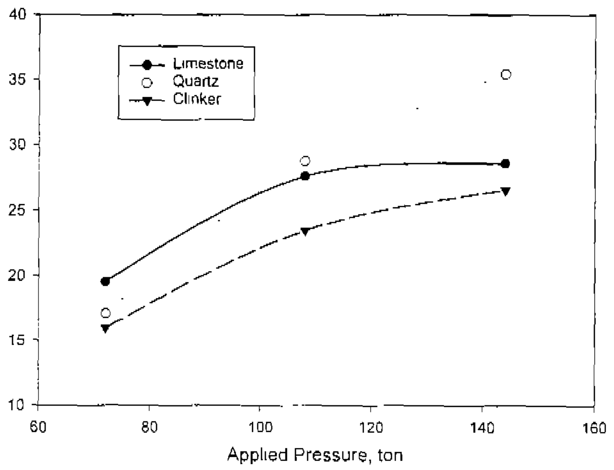

Fig. 8. Regression coefficient b[0] with compressive pressure in the regressional model: Passing %=b[0]+Pressure×b[1].

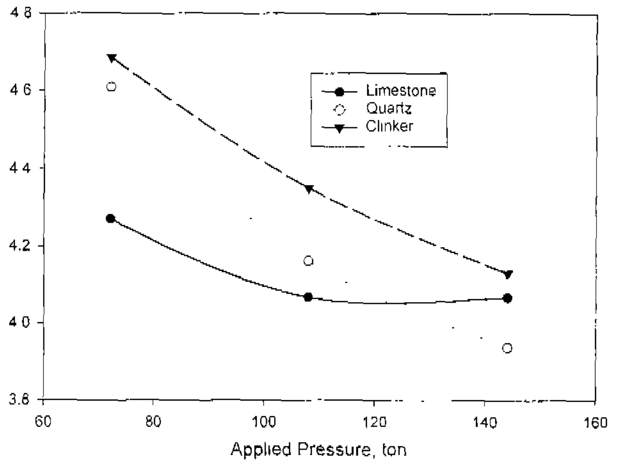

Fig. 9. Regression coefficient b[1] with compressive pressure in the regressional model: Passing %=b[0]+Pressure×b[1].

explaining and quantifying the effect of compressive grinding and the pressure sensitivity of compressive grinding process.

IV. Conclusion

Model experiment of compressive grinding has been designed as an important tool for the investigation on the compressive grinding of raw materials and clinker granule. Quartz is found to be more effective in compressive grinding than limestone and clinker. Regression analysis on the grinding effect provided very useful information in quantifying grinding efficiency. Regression coefficients, b[0] and b[1], in the regression model explain the general grinding effect and the pressure sensitivity during compressive grinding, respectively.

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