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# Physical, Chemical and Electrical Analysis of Dust Generated from Cement Plants for Dust Removal with an Electrostatic Precipitator

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**Abstract**−The physical, chemical and electrical characteristics of cement dust generated from a cement plant have been investigated by using a dust analyzer and a high voltage conductivity cell based on JIS B 9915. Major constituents of raw material cement dust generated from the first grinding process are CaO (41.77%), $SiO_2$ (11.72%), $Al_2O_3$ (3.45%), and $Fe_2O_3$ (1.47%), while the cement clinker dust generated from the second grinding process consists of mainly CaO (48.09-65.50%), $SiO_2$ (14.02-21.56%), $Al_2O_3$ (2.86-3.76%), and $Fe_2O_3$ (1.77-2.66%). Size distribution of the raw material cement dust is bi-modal in shape and the mass median diameter (MMD) is 3.68 μm, whereas the cement clinker dust also displays bi-modal distribution and the MMD of the cement clinker dust is in the range of 7.89-58.78 μm. The resistivity of raw material cement dust is so high as $10^{14}$ ohm·cm at 300 °C, that cement dust would not precipitate well by the electrostatic precipitator.

Key words: Resistivity, Electrostatic Precipitator, Cement Dust, Size Distribution, Chemical Composition

## INTRODUCTION

There are thousands of electrostatic precipitators (ESPs) in operation for the control of emissions from steam generating power plants, cement kilns, sinter plants, and other industrial sources [Choi et al., 2002; Yoa et al., 2001]. Much emphasis has been placed on the fact that effective precipitation coincides with the occurrence of optimum amounts of electrical input in the corona process. While power input is sometimes limited by structure or individual component defects, most limited power installations occur under conditions of excessive electrical resistivity of the collected material. In the design of electrostatic precipitators, the electrical resistivity of the dust is one of several important factors to be considered since the resistivity inversely influences the allowable electrical operating parameters.

The major particulate collection devices used in cement plants are fabric filtration collectors installed more than 90% in Korea. Little information exists in the literature about the performance of electrostatic precipitators for removing dust generated in cement plants. This is understandable since most of the attention in the last few years has been given to coal fly ash electrostatic precipitators [Ku et al., 2000; Steelhammer et al., 1977] and to sinter dust electrostatic precipitators in steel plants [Cho et al., 2002; Lee et al., 2001; Masuda, 1979]. Therefore, most electrostatic precipitators are designed using the data based on the characteristics of coal fly ash such as electrical resistivity, chemical composition, size distribution, and so on. To design the ESP for some particulate emissions from an industrial process, it is necessary to get information related to the emissions. Fig. 1 shows the manufacturing process of the cement industry and the location of the ESPs to collect dust. Cement dust is generated from the first grinding process for the raw

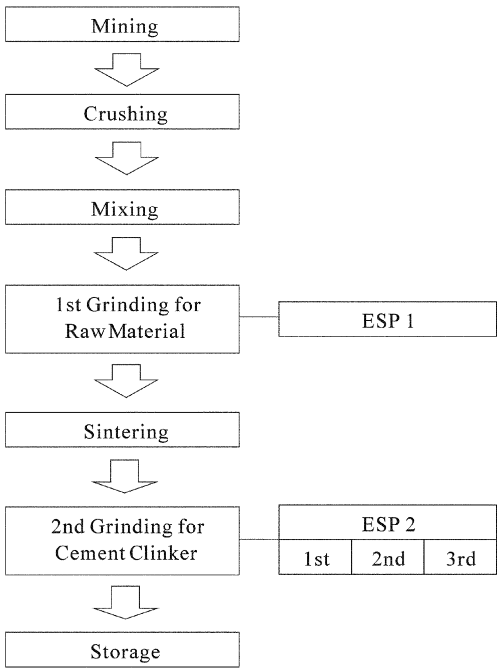

**Fig. 1. Manufacturing process of cement production in the cement industry.**

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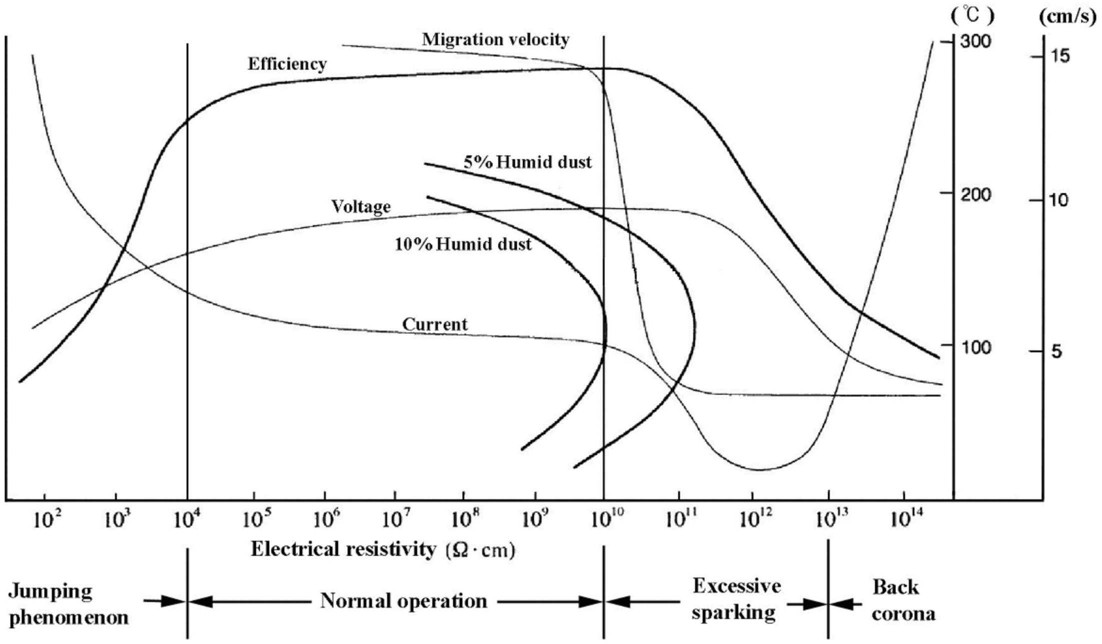


**Fig. 2. Relationship of the dust resistivity and operation parameters in the electrostatic precipitator [Walker, 1968].**

material and the second grinding process for the cement clinker and collected in the ESPs.

The purpose of this study was to investigate the physical, chemical and electrical characteristics of the cement dust generated from a cement plant. This study was also intended to provide some information on collecting cement dust to prevent air pollution. Electrical resistivity has been determined by means of the high voltage conductivity cell based on the JIS B 9915. Dust characterization such as the chemical composition, size distribution, and the surface structure has been conducted and analyzed.

## ELECTRICAL RESISTIVITY

Resistivity can be described as the resistance to charge transfer by the dust. Dust resistivity values can be classified roughly into three groups of low resistivity (<$10^4$ ohm·cm), normal resistivity ($10^4$-$10^{10}$ ohm·cm), and high resistivity regime (>$10^{10}$ ohm·cm) [Beachler and Jahnke, 1981].

Fig. 2 shows the general relationship between the electrical resistivity of dust and the operation variables such as the ESP efficiency, migration velocity, corona voltage, and corona current [Walker, 1968]. If resistivity is too low, below $10^4$ ohm·cm, particles reaching the collecting electrode rapidly lose their charge and become re-entrained in the gas. While if resistivity is too high, above $10^{10}$ ohm·cm, particles are hard to charge, limiting power input. Particles are also slow to lose their charge when they reach the collecting electrode because of the low conductivity of the dust layer already deposited. This increases the voltage gradient across the deposited layer, reduces the charging and collecting fields, and decreases particle migration velocity. If the particulate is very resistive or builds up enough, the voltage gradient across the dust layer causes a dielectric breakdown and a phenomenon called "back corona" occurs in which ions of the charge opposite to those generated at the discharge electrode effectively neutralize the unipolar space charge and severely reduce collection efficiency.

## EXPERIMENTS

### 1. Measurements of Physical and Chemical Properties

The cement dust used in this study was obtained at the raw material dust precipitator and at the 1st, the 2nd, and the 3rd stage of the clinker dust precipitator in the cement industry. The chemical

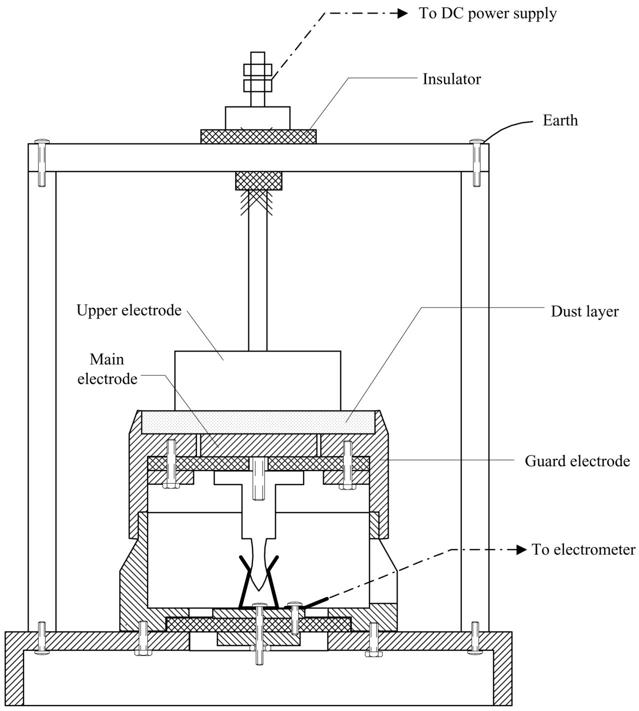


**Fig. 3. Schematic diagram of the high voltage conductivity cell for measuring electrical resistivity of dust [JIS B 9915].**

composition, the particle size distribution, and the surface structure were investigated for dust samples. Chemical composition such as CaO, $SiO_2$, and $Al_2O_3$ was determined by using an X-ray Fluorescence Spectrometer (Philips, PW 2400). A particle counter (Malvern, Mastersizer Micro Plus) was used to determine the particle size distribution. The shape and surface structure of the dust were investigated with a Scanning Electron Microscope (SEM) and an Energy Dispersive X-ray Spectrometer (HITACHI, S-4200).

**2. Resistivity Measurement**

Fig. 3 shows the high voltage conductivity cell used in this study for measuring the electrical resistivity of the dust. Its design is based on the Japanese Industrial Standard JIS B 9915 [JIS, 1989]. The high voltage conductivity cell is composed of two parallel electrodes of a lower electrode loading a dust sample and an upper electrode placed on a dust layer. The lower electrode is composed of a main electrode and a guard electrode. The upper electrode is 35.7 mm in diameter and its total mass is 100 g. It is composed of a high voltage conductivity cell, an electric furnace, a high voltage power supply, and an electrometer. The temperature within the electric furnace can be held at any desired level between room temperature and 450 °C by electric heaters. Dust resistivity is measured after initial temperature is set and the temperature is held for not less than 30 minutes. And then temperature is increased to the next measuring point. The currents are read 2 minutes later after a voltage of DC 2 kV is applied.

Resistivity of the dust is obtained from the experimental data of current density in a given electrical field strength as follows [JIS, 1989]:

$$\rho_d = \frac{E}{J} \qquad (1)$$

where $\rho_d$ is the resistivity of the dust (ohm·cm). E is the electric field strength between two electrodes (V/cm) and J is the current density (A/cm$^2$). Dust layer thickness is 0.5 cm and the cross-sectional area of the upper electrode is 5 cm$^2$. The applied voltage to the high voltage conductivity cell is 2 kV.

## RESULTS AND DISCUSSION

**1. Dust Characterization**

Table 1 shows the results of the chemical characterization of the dust generated from the first grinding process for the raw material and the second grinding process for the cement clinker in the cement plant. The results of elementary chemical analysis are expressed in weight percent of oxides. The raw material dust of the first grinding process primarily consisted of CaO (41.77), $SiO_2$ (11.72%), $Al_2O_3$ (3.45%), and $Fe_2O_3$ (1.47%). On the other hand, the 1st stage cement clinker dust of the second grinding process mostly made up for CaO (63.40%) and other main constituents of $SiO_2$ (20.99%), $Al_2O_3$ (3.76%) and $Fe_2O_3$ (2.66%). However, the 3rd stage cement clinker dust consisted of CaO (48.09), $SiO_2$ (14.02%), $K_2O$ (8.67%), $Fe_2O_3$ (1.77%), and the other constituents similar to the 1st stage cement clinker dust. For the dust generated from the second grinding process for the cement clinker, most large particles are collected in the 1st stage of the cement clinker ESP due to the gravitational settling, while smaller particles are captured in the rear stages. The electrical resistivity decreases with increasing $Fe_2O_3$ fraction because of its conductive characteristics [Lee et al., 2001]. As shown in Fig. 6, the lower the fraction of $Fe_2O_3$ component, the higher the electrical resistivity.

Fig. 4 shows the size distribution of the dust generated from the first grinding process for the raw material and the cement clinker dust from each stage of ESP. The raw material dust displays bi-modal distribution with dust in the coarse (>5.0 μm) mode and in the fine dust mode. The MMD of the raw material dust is 3.68 μm. The size distributions of the each stage cement clinker dust are also bi-modal in shape and the mass median diameters (MMD) of the dust in the 1st, 2nd, and 3rd stages are measured as 58.78, 35.20, and 7.89 μm, respectively. Most large particles are collected in the 1st stage of the cement clinker ESP due to the gravitational settling, while smaller particles are captured in the rear stages. In general, the electrical resistivity is not related with the particle size and the same

**Table 1. Chemical characterization of the cement dust**

| Chemical composition | Dust generated from the first grinding process for raw material | Dust generated from the second grinding process for cement clinker | | |
|---|---|---|---|---|
| | ESP1 | ESP2 | | |
| | | Stage 1 | Stage 2 | Stage 3 |
| $SiO_2$ | 11.72 | 20.99 | 21.56 | 14.02 |
| $Al_2O_3$ | 3.45 | 3.76 | 3.44 | 2.86 |
| $Fe_2O_3$ | 1.47 | 2.66 | 2.60 | 1.77 |
| MnO | 0.08 | 0.21 | 0.23 | 0.15 |
| CaO | 41.77 | 63.40 | 65.50 | 48.09 |
| MgO | 0.97 | 2.01 | 1.53 | 1.22 |
| $K_2O$ | 0.90 | 1.70 | 1.75 | 8.67 |
| $Na_2O$ | 0.26 | 0.51 | 0.51 | 0.71 |
| $P_2O_5$ | 0.08 | 0.16 | 0.18 | 0.12 |
| $TiO_2$ | 0.19 | 0.21 | 0.21 | 0.15 |
| L.O.I* | 35.42 | 1.83 | 1.35 | 10.61 |
| Particle size (μm) | 3.68 | 58.78 | 35.20 | 7.89 |

*L.O.I: Loss on Ignition

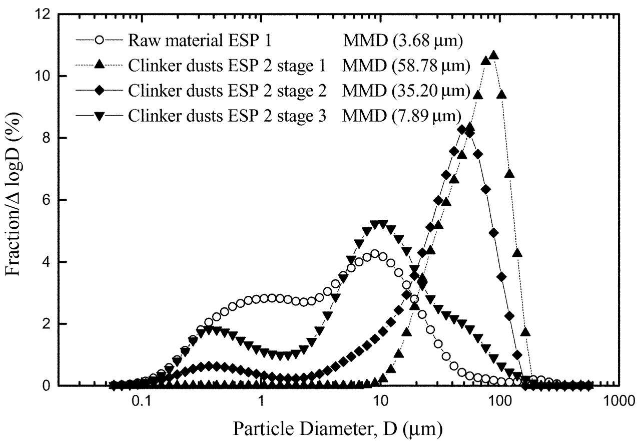


**Fig. 4. Size distributions of the raw material dust collected from the ESP 1 and the cement clinker dust collected from the ESP 2 stages.**

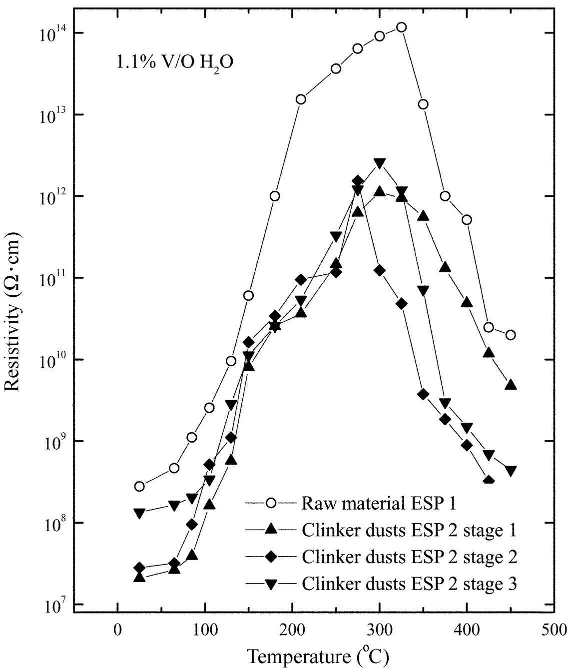


**Fig. 5. Resistivity variation of the raw material dust and the clinker dust as a function of temperature.**

results are obtained from the experimental results. The shapes of the raw material dust and the cement clinker dust are polygonal and irregular forms.

**2. Electrical Resistivity of the Cement Dust**

Fig. 5 shows the resistivity variation of the dust generated from the first grinding process for the raw material and the second grinding process for the cement clinker as a function of temperature. At the temperature range of 25-300 °C, the resistivity of the raw material dust increases with increasing temperature, while for high temperature above 300 °C, it decreases steeply with increasing temperature. At temperature range 25-300 °C, current conduction occurs principally along the surface layer of the dust and the resistivity is related to the absorption or adsorption of water vapor in the air. At high temperature range, conduction takes place primarily through the bulk of the dust; therefore, resistivity depends on the chemical composition of the material [Lee et al., 2001]. The highest resistivity is about $10^{14}$ ohm·cm at 325 °C. The resistivity of the raw material dust in the vicinity of operation temperature of 160 °C is $3.7\times10^{11}$ ohm·cm. On the assumption that back corona can be avoided for resistivities less than $10^{10}$ ohm·cm, the raw material dust probably would not precipitate well in the vicinity of operation temperatures due to the dust characteristics of high electrical resistivity.

The resistivity of the cement clinker dust for all three ESP stages in the vicinity of operation temperature of 180 °C is similar and ranges from $2.56\times10^{10}$ to $3.41\times10^{10}$ ohm·cm. Dust generated from the second grinding process for the cement clinker would not precipitate in the ESP since the resistivity of the raw material dust is in the high resistivity region.

In general, increased moisture content of ambient air lowers the dust resistivity because current conduction is more activated for absorption or adsorption of water vapor on the surface layer of the dust [Lee et al., 2001]. For the common high resistivity dust collected from industrial precipitators, the operation becomes more efficient and trouble-free with increasing the moisture content of the gas by the use of water spray and steam injection.

## SUMMARY AND CONCLUSION

The electrical resistivity of raw material dust and cement clinker dust generated from the cement industry has been investigated as a function of temperature. Electrical resistivity has been determined by means of the high voltage conductivity cell based on the JIS B 9915. Dust characterization with such as the chemical composition, size distribution, and surface structure has been conducted.

The raw material dust consisted of mainly CaO, $SiO_2$, $Al_2O_3$, and $Fe_2O_3$, and the cement clinker dust showed similar results. Size distributions of the raw material dust displayed bi-modal distribution and the MMD was 3.68 μm, whereas the cement clinker dust was also bi-modal in shape and the MMD was in the large range of 7.89-58.78 μm.

Factors affecting resistivity of dust were chemical composition, particle size, gas temperature, and surface structure of dust. The raw material dust and the cement clinker dust were classified as one of relatively high resistivity. The resistivities of the raw material dust and the cement clinker dust were as high as $5.53\times10^{11}$ ohm·cm at 160 °C and $2.56\text{-}3.41\times10^{10}$ ohm·cm at 180 °C, respectively. Therefore, the cement dust would not precipitate well due to the dust characteristics of high electrical resistivity.

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