Utilization of the Coal Ash as Filler of Plastics and Rubber Products

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Abstract: Not only for us but for Japan aiming for sound material-cycle society, it is an important problem to utilize the coal ash remained after combustion of coal as useful resources. Therefore, we are struggling to develop the utilization of the coal ash in several ways. As part of the action, we tried to apply the coal ash to filler of plastics and rubber. Consequently, we found that the coal ash could be used as filler like calcium carbonate which was used well.

Keywords: Coal ash, Fly ash, Filler, Plastics, Rubber

1. INTRODUCTION

There are 38 coal-fired power staitions (74 power plants) in various places of Japan for December, 2003[1]. The total power generation output is 35 million kW. 7.24 million tons of fly ash are produced secondary by coal-fired power plants a year. And 6.97 million tons are chiefly recycled as the cement raw material, the concrete mixture material, and the land reclamation material, etc[2]. Our company has the only coal-fired power station in Hekinan city, Aichi prefecture. The output of Hekinan Thermal Power Station is 4.1 million kW. About 0.9 million tons of coal ash is produced by this power plant a year. This amount accounts for about 70% of our industrial waste. Therefore, the research and development to attempt utilization by high-value-added is advanced besides the recycling method mentioned above.

Fig. 1 Hekinan Thermal Power Station

The coal ash is divided roughly into bottom ash and fly ash (Refer to Figure 2). As shown in Figure 3, bottom ash looks similar to sand. The principal ingredient is silica and alumina. It is a material with high specific surface area that there are innumerable minute holes of 1-20μm in the surface of the particle. Therefore, bottom ash is used as the lower road board material and the planting soil, etc. On the other hand, fly ash is a minute globular particle and average particle size is 20-30μm as shown in Figure 4. It is a vitreous material and the principal ingredient is silica and alumina. Fly ash is used for mortar and concrete as a mixture thing. To promote effective use in a cement concrete field, the quality control based on JISA6201 is done as shown in Table 1. Besides, effective use to an industrial raw material is expected as a high-quality inorganic material.

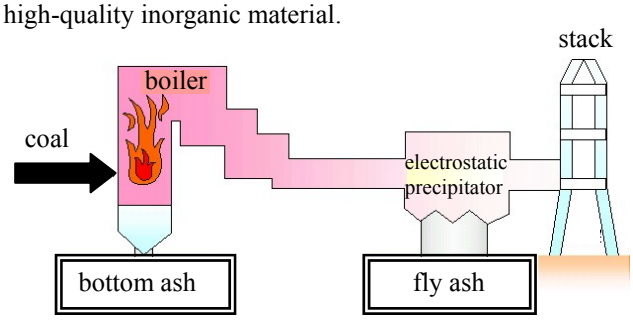

Fig.2 The place where coal ash was captured

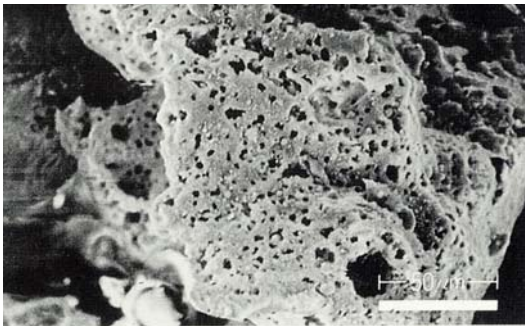

Fig.3 Electron micrograph of bottom ash

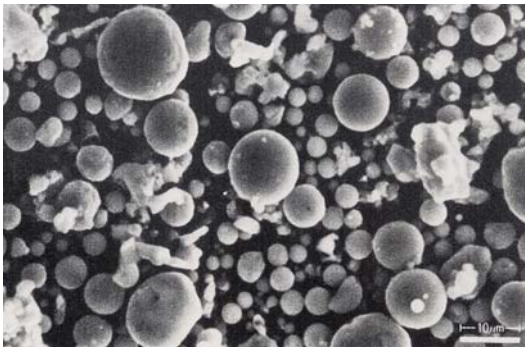

Fig.4 Electron micrograph of fly ash

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In general, physical properties of rubber and plastics are improved by filling materials such as calcium carbonate, clay, and talc. They are used in a lot of fields such as the car, construction, electronics, sporting goods, furniture, and electrical appliances. Because fly ash contain effective components of filling materials like calcium carbonate, talc,and clay, we tried to add fly ash to rubber and plastics, and researched on the performance of products added fly ash.

2. APPLICATION OF FLY ASH TO RUBBER

2.1 Evaluation of basic physical properties

The carbon black, calcium carbonate, the clay and silica is used as a filling material for rubber. And they play a role in the reinforcement and the increase. The particle size of calcium carbonate is under 15μm in case of using as filling materials. Because particle size of fly ash is 20-30μm and close to one of calcium carbonate, we considered using fly ash as a substitute of calcium carbonate. In general, rubber products are made as follows. First, Polymer, filling material, the vulcanized agent and the vulcanization accelerator are mixed in mixture machine. Secondly the compound is turned on to the metal mold, and then rubber is vulcanized and built. So we tried to substitute fly ash for the filling material, we investigated into the effect of the material physical properties.

Table 2 shows the mixing composition of the material. Labo Plastmill (250 cc, Toyo Seiki Seisaku-sho, Ltd.) was used for the mixture of the material. The vulcanization condition was 100 kgf/cm^2, 150 ℃ and 30 minutes.

Table 3 shows physical properties of the material. About fly ash mixture rubber, the Mooney viscosity tends to rise compared with calcium carbonate mixture rubber (No.1~3), and to become early Scorch time. Moreover, some tensile strength rose, and hardness and the expansion were almost equal. It is almost similar to calcium carbonate about the machine physical properties.

Next, tensile strength is lower than the cases to add the carbon black (No.4), and there is no effect of reinforcement like the carbon black in the fly ash. For the reasons mentioned above, it is possible for rubber to mix fly ash as substitution of calcium carbonate.

Table 1 JISA6201

		type Ⅰ	type Ⅱ
SiO_2, min. %		45	45
Moisture content, max. %		1.0	1.0
Ignition loss, max. %		3.0	5.0
Density, min. g/cm^3		1.95	1.95
Fineness, retained 45 μm sieve, max. %		10	40
Specific surface area, min. cm^2/g		5,000	2,500
Percent flow Portland cement, min. %		105	95
Strength activity index Portland cement	28days, min %	90	80
	91days, min %	100	90

Table 2 Recipe of compounds

	No.1	No.2	No.3	No.4
Fly ash	100	50	-	90
Limestone powder	-	50	100	
SBR	100	100	100	100
Carbon black	-	-	-	10

Table 3 Properties of the rubber filled fly ash

	Unit	No.1	No.2	No.3	No.4
Mooney viscosity (ML_{1+4}100)	-	69.6	64.6	57.3	61.9
Mooney scorch time	min	13.4	14.8	18.6	8.5
Tensile strength	kg/cm^2	25.3	22.5	18.0	40.7
Elongation	%	500	450	500	380
Hardness	-	64	62	60	71

2.2 mixture examination

From the basic physical properties evaluation, it was confirmed to be able to apply fly ash as a filling material. However, the examination mentioned above is the result of the small size machine. So we investigated into the arrangement of fly ash in rubber when the blending machine is enlarged. Fly ash mixture rubber (No.1) was mixed with a mixer of 5L(internal mixer 5L made by Mitsubishi Heavy Industries), and the section was observed with the light microscope. An optical photomicrograph in the section of rubber filled fly ash is shown Figure 5. Fly ash disperse equally and don't cohere.

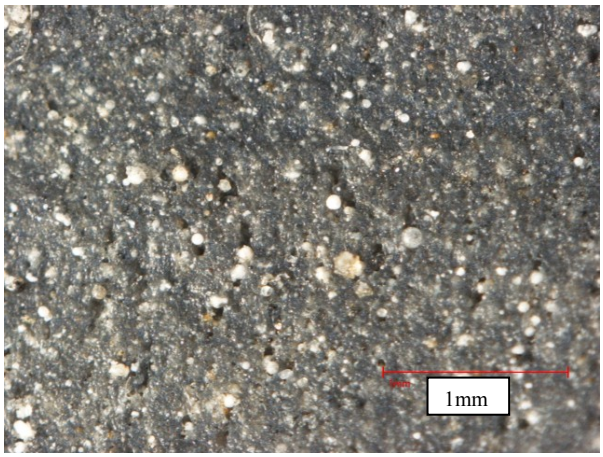

Fig. 5 Sectional picture of rubber filled fly ash

2.3 Diameter comparison

It is necessary to pay attention to the particle diameter of the filling material because it may have a influence on physical properties. So we manage the particle size of fly ash by measuring the specific surface area based on JISA6201. However, the specific surface area changes within a certain constant range because it burns many kinds of coals. Then, to confirm the influence by the difference of the specific surface area, physical properties of rubber that filled three kinds of fly ash of the specific surface area 3,100 cm^2/g (No.5), 3,500 cm^2/g (No.6), and 3,800 cm^2/g (No.7) were measured.

Table 4 shows influence of the particle diameter. Remarkable decrease of performance is not admitted even if the specific surface area of the coal ash.

Table 4 Influence of the particle diameter of fly ash

	Unit	No.5 (3,100)	No.6 (3,500)	No.7 (3,800)
Mooney viscosity ($ML_{1+4}125$)	-	17.1	19.0	18.1
Mooney scorch time	min	12.5	11.6	12.5
Tensile Strength	MPa	7.2	6.8	6.4
Elongation	%	520	480	500
Hardness	-	56	57	57

2.4 Confirmation examination of molding

From the results mentioned above, it is found that fly ash is used as substitution of calcium carbonate in the examination of the laboratory level. So we produce the rubber mat for prevention of weed experimentally with INOAC CORPORATION. The trial rubber mat size is 2000mm in length ×1000mm in width × 15mm in thickness and filled fly ash by 32 weight%. As a result, we confirmed the big size mat (Show in Figure 6) was able to be made.

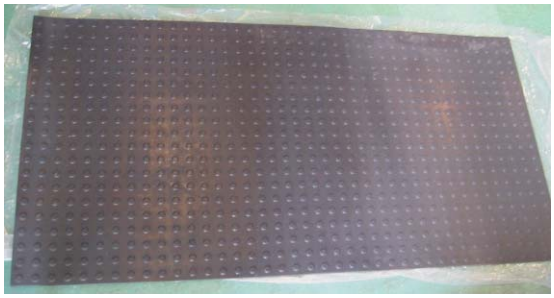

Fig. 6 Rubber mat

3. APPLICATION OF FLY ASH TO UNSATURATED POLYESTER

3.1 Basic mixing examination

A lot of inorganic materials such as calcium carbonate and sand are contained in the unsaturated polyester resin product such as construction materials. The thermosetting unsaturated polyester is molded with heating in the metal mold up to 160-190℃. We measured the liquidity of the mixture raw material that substituted fly ash for an inorganic material and the machine physical properties after it had been molded.

(1) Liquidity

About the mixture raw material shown in Table 5, Liquidity in the metal mold was examined. As for the examination, the extension when the mixture raw material put on the center of the metal mold heated to 140℃ was pressed it with 5 kgf/cm^2 was measured. Figure 7 shows the results. Liquidity equal with standard mixing was shown in Test1, and molding enough became clear. In addition, liquidity became worse in Test 2 that adds the fly ash in place of sand. This cause may depend on an increase at the volume ratio rate of an inorganic material by having mixed the coal ash with small bulk specific gravity compared with sand.

Table 5 Recipe of compounds (weight%)

	Standard	Test 1	Test 2
Unsaturated polyester	13	13	13
Glass fiber	5	5	5
Calcium carbonate	35	0	0
Sand	47	47	27
Fly ash	0	35	55

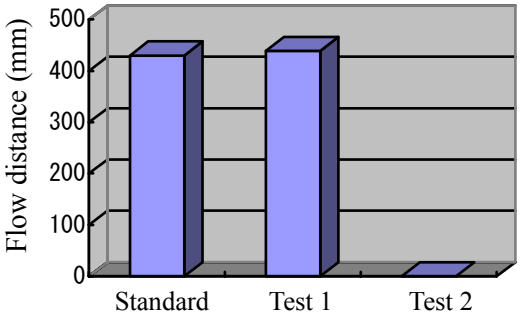

Fig. 7 Change of flow distance with the addition of fly ash

(2) Mechanical properties

The bending strength and the impact strength were measured as mechanical properties. The bending strength was calculated from the maximum load in the center part of the strip specimen. The impact strength was evaluated by Charpy impact test. The bending strength was almost equal to a standard mixing in Test1 as shown in Figure 8 though it had decreased up to about 60 % in the Test2 mixing. Moreover, the impact strength measurement result was shown in Figure 9, and about 65 % of a standard mixing in Test1. Because Fly ash is spheroidal while calcium carbonate is squarish, the mixed fly ash tend to come off the resin by the impact easily.

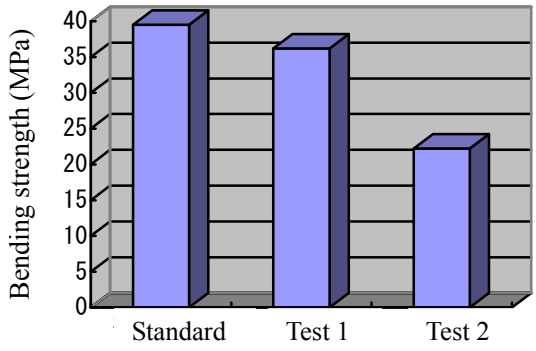

Fig. 8 Change of bending strength with the addition of fly ash

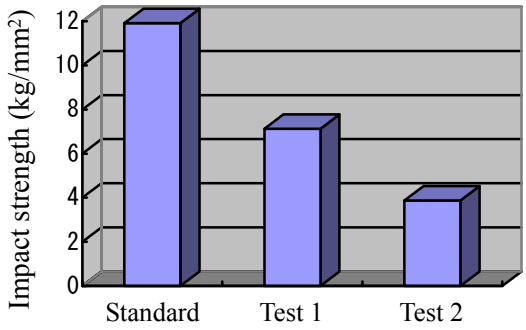

Fig. 9 Change of impact strength with the addition of fly ash

3.2 Molded confirmation examination

The possibility to use fly ash as calcium carbonate substitution was found though it was necessary to select the product that did not need high impact strength. Then, the practical use machine (maximum load 400 t) made manhole cover (300 φ) for trial products, and molding was confirmed. It was confirmed to be able to mold a manhole lid of complex pattern as shown in Figure 10.

Fig.10 Picture of the cover of manhole

4. CONCLUDING REMARKS

We are aiming at the adoption of fly ash as the substitution of calcium carbonate that is an existing filling material, and are working on the grasp of user needs and the usage development now. And we continue to promote the research and development of utilization for fly ash.

5. ACKNOWLEDGMENT

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REFERENCES

1. Japan Fly Ash Association, Coal Ash (in Japanese)
2. The Federation of Electric Companies of Japan, Environmental Action Plan by the Japanese Electric Utility Industry (in Japanese)