Are Fly Ashes Green?

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1. Introduction

Now at days, the color “Green” makes the image of an “environmental friendly” product. There is a psychological effect that gives the image of nature in those products. In fact, the word “green” as in “green chemistry” or “green new deal” are including the sense of “sustainable”. These social movements are very important for the use of coal and CCPs policies statements, but there are very few researches from this point of view. The first step in this research is the real original sense of color ”green” of fly ashes.

The part of coal ash produced in large quantities at coal fired power stations, called fly ash, found to be a good quality pozzolan has come to be used in fly ash cement, masonry mortar, joint sealers, etc., and more recently, its large-scale use as a substitute for fine aggregate in concrete has been under study. In such case, only monochrome light and shade have been paid attention when fly ash is used in mortar and precast concrete. Furthermore, measurements have been carried out only of Hunter brightness or reflectivity, while extremely little evaluation as a material possessing color has been made. The authors thought that not only measures against color irregularity were needed, but also that it was necessary to positively examine the possibility of using fly ash as a coloring material. Notable conclusions have been reached in this research.

2. Evaluation Method

Coal ash, or fly ash (JIS A 6201) in this paper is generated at coal fired power stations, derived from soot collected by electric precipitator. It is herein the analysis result of samples from a total of 300 lots, 220 lots from 40 locations in Japan and 80 lots from other countries. The references were 20 lots of OPC(ordinary Portland cement), 16 lots of powders each of blast furnace slag and limestone, all assumed to have a Blaine specific surface area of 4000m^2/g.

The chemical composition analyses and laboratory tests performed were: pH(25% slurry), specific gravity, mean particle size, spherical percentage, and Munsell colorimetric (according to JIS Z 8721). The samples were put in 0.2mm-thickness polyethylene bags and measurements were performed from the surfaces of the bags. The varieties of wood and brick as construction materials were also tested.

In colorimetric, the Munsell system is a color space that specifies colors based on three dimensions: Hue, Value (lightness), and Chroma (color purity). Created by Professor Albert H. Munsell in 1905, each horizontal circle Munsell in the system is divided into five principle hues: Red, Yellow, Green, Blue, and Purple, along with five intermediate hues halfway between adjacent principle hues. Each of these ten categories is then divided into ten sub-categories, so that 100 hues are given integer values. Figure 1 shows Munsell color circle. Two colors of equal values and chromas, on opposite sides of a hue circle are complementary colors, and mix additively to neutral gray of the same value.

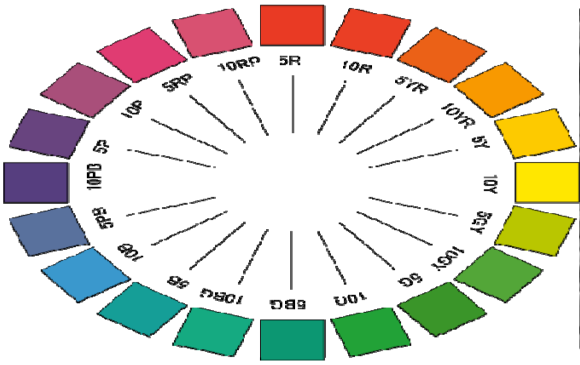

Figure 1 Munsell color circle.

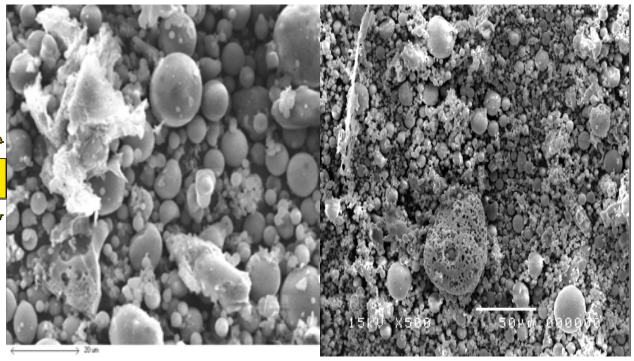

Figure 2 SEM picture of Fly ash 88↓ and 22↓

3. Results of Measurement and Comments

Table 1 shows a part of the results of measurements performed on coal ashes. Figure 2 shows the sample of 2 different spherical type. The ashes had wide scattering of values and tones compared with cement, blast furnace slag, and limestone powder. Regarding tones, cement and others got hues in the Y-G system. The coal ashes tended to be in the R-P system due to the influence of no combusted carbon which contained a considerable difference. Many of the samples were concentrated in the Y-YR area, the hues of samples from which no combusted carbon had been removed, and thought to be from content of Fe_2O_3.

This hue coincided with that of wood and brick used extensively in building construction in Japan from the past. The colorings of wood and brick give a feeling of “warmth” while the surfaces of mortar and limestone present coloring of the G-Y system: “cold and inorganic”.

Figure 3 gives the relation between hue and spherical of coal ash and it shows that hue changes with spherical particle rate changes. The tendency in a single power plant is of one pattern, and variations in kind and combustion conditions of coal can be readily grasped. The conglobation rate of the coal ash is one of the principal items expressing characteristics as a pozzolan. It has a correlation with the amount of content other than spheres, that is, no combusted carbon, which greatly affects water ration and admixture dosage requirements in mortars. The measurement method formerly required electron microscope observation and measurements by human eye, but the hue measurement has become possible for automation of quality control.

Figure 4 shows the relation between Chroma(C) of coal ash and CaO+MgO content. Although only coal ash samples of no combusted carbon contents not more than 5% and average particle diameter of 15 micrometers. There was a tendency for color(C) of coal ash to become stronger with increase in CaO+MgO content. This CaO+MgO content controls the degree of progress of mortar and concrete carbonation or surface characteristics by supplying anions and controls dosage requirements of water-reducing agents. In simplest way, the quality control consists of pH measurement of slurry of coal ash, and results are obtained in

Table 1 A part of the results of the Measurements

	power station	coal	Ig.loss(%	SiO2(%)	Fe2O3(%	CaO+MgO(	pH	gravity	Size	Spha%	MunsellH	V	C
A	USA	USA	1.3	33.6	7.4	31.6	12.3	3.01	9.9	98	1.4Y	7.5	2.1
B	China	China	1.0	56.4	7.2	20.4	12.8	2.49	15.9	88	1.0Y	6.0	1.3
C	Thailand	Thailand	1.0	41.0	13.2	16.0	11.8	2.41	13.4	93	8.7YR	6.0	1.0
D	JAPAN	JAPAN	1.3	53.8	9.2	10.8	12.0	2.30	10.5	98	1.7Y	6.8	1.0
E	JAPAN	USA	1.9	66.4	1.7	2.8	9.7	2.30	17.2	82	6.2Y	6.6	0.3
F	JAPAN	JAPAN	1.8	53.2	6.3	8.5	12.0	2.18	15.3	93	0.1Y	6.3	0.5
G	JAPAN	Australia	2.3	67.3	5.4	1.5	7.5	2.26	13.5	77	4.4Y	6.4	0.2
H	JAPAN	China	1.4	56.4	5.5	8.5	12.2	2.19	17.3	92	9.8YR	6.6	0.7
I	JAPAN	Australia	3.5	60.9	4.8	4.1	10.7	2.22	15.9	85	8.4R	5.6	0.3
J	JAPAN	Canada	17.2	40.0	4.3	12.1	12.7	2.24	16.2	10	9.5R	5.3	0.8
K	JAPAN	Indonesia	3.0	49.2	6.9	11.8	12.0	2.20	16.1	93	8.6RP	5.8	0.5
L	JAPAN	Australia	26.3	35.7	4.9	6.3	9.5	2.09	24.5	8	5.8P	4.9	0.3
M	Australia	Australia	4.9	67.3	1.8	0.9	1.9	2.18	20.5	8	3.1P	6.4	0.0
I’	J-separate	Australia	3.5	61.2	4.2	5.0	10.0	2.36	5.0	92	2.0Y	6.6	0.5
L’	J-separate	Australia	25.4	36.6	4.8	5.9	8.5	2.26	10.9	15	2.9RP	4.9	0.4
I’’	J-reburt	Australia	0.0	63.1	2.9	4.2	9.9	2.71	15.4	78	8.5YR	7.6	2.1
220 Lot	JAPAN	upper	26.9	67.8	11.6	14.3	13.0	2.51	40.1	99	5.8GY	7.5	2.1
total	JAPAN	lower	0.3	35.7	1.8	0.6	1.9	1.98	1.7	8	3.1P	4.2	0.0
300Lot	World	upper	26.9	71.5	13.9	30.4	13.0	3.01	53.6	99	5.8GY	7.5	2.1
total	World	lower	0.3	25.9	0.9	0.6	1.9	1.98	1.7	7	3.1P	4.2	0.0
OPC	JAPAN	upper	2.3	21.7	3.2	67.1	12.4	3.16	17.0	3	4.7Y	6.4	0.8
total	JAPAN	lower	1.8	20.8	2.8	65.5	12.2	3.14	14.2	2	2.8Y	6.2	0.6
white C	JAPAN		2.3	24.2	0.7	66.4	12.3	3.19	8.9	3	0.7G	9.4	0.6
blast f.	JAPAN	upper	0.6	34.4	0.6	49.1	11.4	2.92	11.1	2	2.0GY	8.7	0.5
slag	JAPAN	lower	0.4	31.9	0.3	47.9	10.9	2.89	9.8	1	4.8Y	8.2	0.7
Limestone	JAPAN	upper	43.6	1.8	0.1	56.1	9.6	2.80	10.1	3	2.5GY	9.4	0.5
powder	JAPAN	lower	40.4	0.0	0.0	54.3	8.1	2.71	6.9	1	3.6Y	7.0	0.1
Oak wood	JAPAN										6.0YR	4.7	3.0
Chinese ink	JAPAN										0.1PB	2.4	0.2
Kanto clay	JAPAN										5.7YR	6.1	2.7
Efflorescence	JAPAN										5.0GY	6.3	0.5
Pigment red	JAPAN										5.8R	4.6	4.6
Pigmentblack	JAPAN										6.0PB	6.3	0.5

case of extreme acidity. However, it is important “warning” information can be gained through automatic luminosity measurements before anyone has to get in trouble of preparing slurry.

Even though chromas of coal ashes are markedly lower than those of pigments, generally in mortar and concrete, repair materials made of coal ashes do not stand out conspicuously from surroundings. Fluidity is excellent since fly ash particles have spherical configuration not found in pigments. Additionally, the use as repair material is promising. Regarding the brightness (V), the results from past reflectivity measurements were not obtained.

Examples of changes in Hue (H) of coal ashes subjected to humidification are given the uneven results. It is thought, that the differences in absorption characteristics, additional substantial changes in light reflection and photo-absorption is due to different levels of filling; further examination of this matter is required.

Figure 5 shows examples of Hue variations of dry-mixed coal ashes with cement (OPC). The results suggest that it is possible to produce numerous “in-between” colors as coal ash addition. Especially, it is thought that the effect of adding R-P system Hues to cement will be great. However, it must be kept in mind that the source of R-P coloring is no combusted carbon. Therefore, it will be necessary to maintain a balance with adverse effects when using this technique. Further research must be required regarding the effect of aggregate addition and time-dependent changes in hardened products.

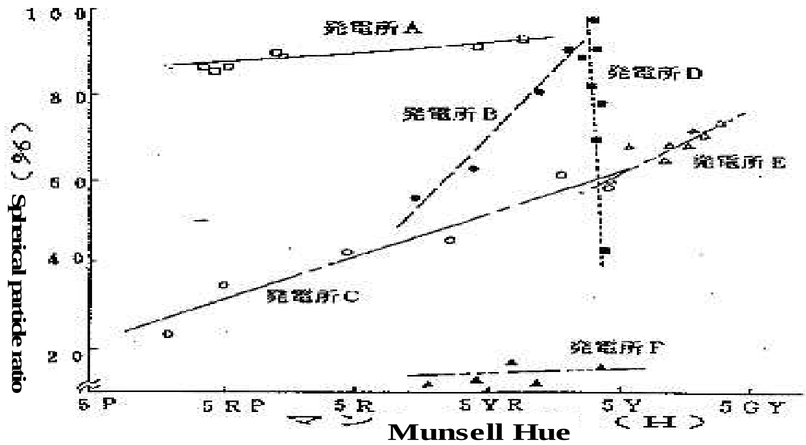

Figure 3 Relation between hue and spherical of coal ash

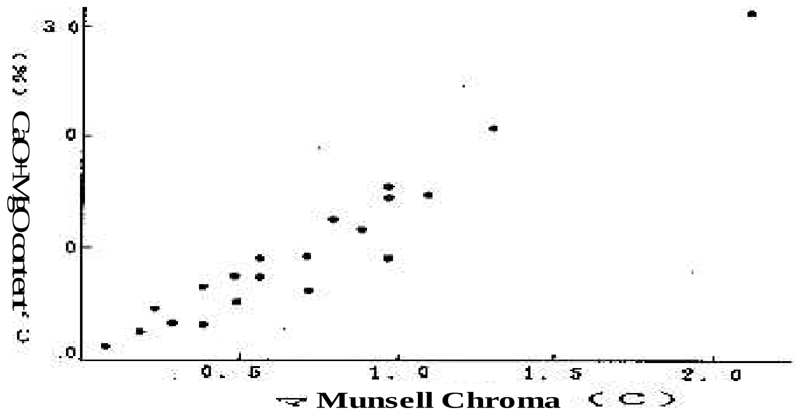

Figure 4 Relation between Chroma(C) of coal ash and CaO+MgO content.

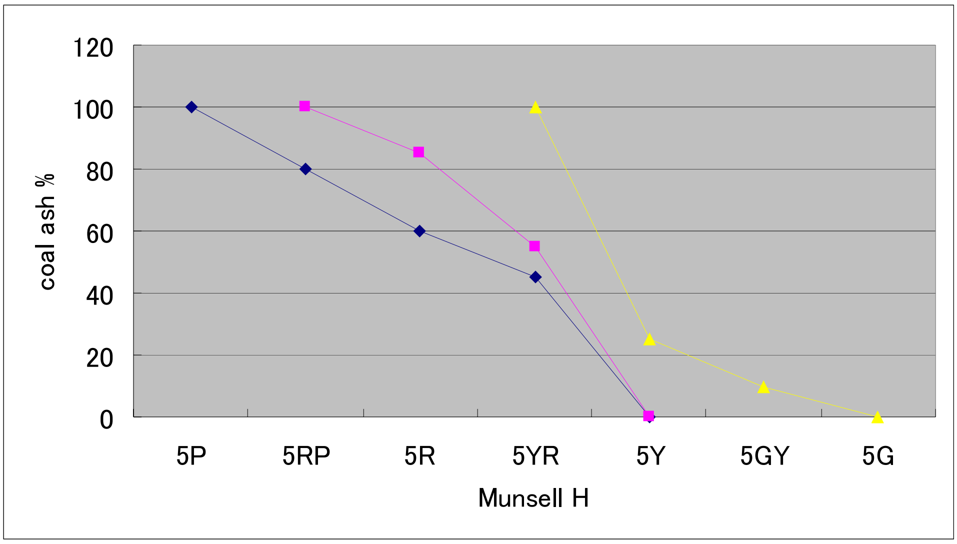

Figure 5 Hue variations of dry-mixed coal ashes with cement

4. CONCLUSION

1. As a result of analyzing 300 lots of coal ash samples. It was determined that coal ash, due to the effect of no combusted carbon content, possesses a wide range of color Hues not seen in cement and other admixtures.
2. Munsell Hue of coal ashes are from GY to P color region, small green samples. Especially coal ash shows green color with mixing the cement.
3. Strong correlations can be seen between Hue and spherical particle rate, Chroma(C) and CaO+MgO content of coal ash. It should be possible to use these as quality control standards.
4. It is suggested the application of a color adjustment additive to repair materials, architectural concrete, and other uses.
5. In sense of "Environmental Green" are other aspects than color and in the future study.

References

[1] T. Tanosaki et al: Research of Fly ashes as concrete admixture in control and management, JCI17 proceedings pp.337-342.1995(In Japanese)