RESEARCH ON THE QUALITY DISTRIBUTION OF JIS TYPE-II FLY ASH IN JAPAN

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ABSTRACT

In Japan, approximately 8 million tons of coal ash is being produced by the electric company every year as the by-product from coal-fired thermal power plant. The volume is expected to grow further due to the new construction and expansion of coal-fired thermal power plant in the future.

The use as the mixture material for concrete is the most effective use for fly ash from the viewpoint of large amount of consumption.

We collect test records of JIS Type-II fly ash shipped in recent years from 24 places of each electric power station in the whole Japan for about two years. The number of data is about 450.We research about the statistical distribution of the data referring the background of present JIS standard value.

1. INTRODUCTION

Since the petroleum crisis, thermal power plants in Japan have diversified their fuels from the viewpoint of ensuring stable supply of electric power, by actively promoting conversion from petroleum-based thermal power generation to LNG and coal fired thermal power generation. The transition in the composition of power generating equipment according to the Power Supply Planning for 2006 by the Ministry of Economy, Trade and Industry (METI) of Japan is shown in Fig.1.

Coal fired thermal power generation equipment at present occupies 16% of the total power generation equipment, and it is estimated that this component ratio will remain substantially unchanged [1)].

Figure 2 illustrates the amount of production of coal ash, amount of its utilization, amount of coal ash land filled and amount of coal consumption in the nationwide electric utilities and other general industries from 1994 to 2004. As is observed from Fig.2, the amounts of its production and utilization are continuously increasing every year, while the amount land filled is in gradual decrease [2)]. That is, the amount of production of coal ash in the nationwide electric utilities and other general industries are in continuous increase, and has reached 10.85 million tons in 2004 (total of utilization and landfill), exceeding 10 million tons, and still maintains an upward trend.

On the other hand, the amount of coal ash used for land filling that is 1.07 million tons in 2004 is currently decreasing.

Furthermore, large scale coal fired thermal power plants of the electric utilities and also those of independent power producers (IPP) are expected to be put into operation in near future, with anticipated increase in the amount of production of coal ash. However, as siting a large scale ash disposal facility is becoming more and more difficult, the amount of coal ash used for land filling will remain in a downward trend. In other words, existing ash disposal facilities shall be made best of, even for increasing amount of coal ash produced, which means that the life of these facilities shall be prolonged, and also that the effective utilization of coal ash other than land filling shall be established as an urgent business.

About 90% of coal ash produced in Japan is fly ash, with the remaining about 10% being clinker ash [3)]. Among various technologies that are being developed for effective use of fly ash, the use as an admixture for concrete is considered the most effective one from the viewpoint of consuming a large amount of fly ash and of reducing the amount of CO^2 emission.

Published literatures provide information on variations in the quality of fly ash discharged from certain specified power plants for several years. However, there is no investigation & research made on the general quality distribution of JIS type concrete-use fly ash available nationwide in the market.

In the present research, recent test reports for about two years regarding the concrete-use fly ash that was delivered from coal fired thermal power plants of electric power companies nationwide were collected. The number of total data gathered is about 450. Based on statistical treatment of these data, and against the current JIS standard, investigation and examination were made on the quality distribution of concrete-use fly ash delivered from coal fired thermal power plants.

2. QUALITY CONTROL OF FLY ASH

2.1 Quality control flow of fly ash

Fly ash produced in coal fired thermal power plants of Japanese electric power companies undergoes three stages of quality control according to the manufacturing processes; recovery quality control, manufacturing quality control and delivery quality control. Each stage has its own quality test items, acceptance criteria and test frequency to be observed in these tests.

Figure 3 shows the quality control flow for fly ash, while Table 1 lists up quality control items for "M" coal fired thermal power plant as an example.

2.2 Recovery quality control and manufacturing quality control

During the recovery process, a quality test is performed to determine acceptability of fly ash collected in the hopper of an electric precipitator to meet the specification of JIS type fly ash. (Fig.3 (1)) Although the hue of fly ash is judged at this stage, it is generally accepted if it is of a color tone similar to that of cement. Fly ash recovered from the raw powder silo is subject to quality testing before and after classification, to confirm that a specified quality is obtained through classification. (Fig.3 (2), (3)) After classification, fly ash stored in the fine powder silo undergoes quality testing, and is transferred to a blending silo, if installed, for further homogenization. (Fig.3 (4))

2.3 Delivery quality control and submission of quality test reports

Fly ash is delivered by means of land transportation using vehicles or marine transportation using vessels. Land transportation uses bulk freight or bailing freight, in either case of which delivery quality is confirmed. (Fig.3 (5)) In case of marine transportation, where a large quantity of fly ash is shipped at a time, it is customary to perform a vessel-based quality control. (Fig.3 (6)) In accordance with the stipulation of JIS A 6201, fly ash quality test results are submitted from the supplier to users as fly ash test reports.

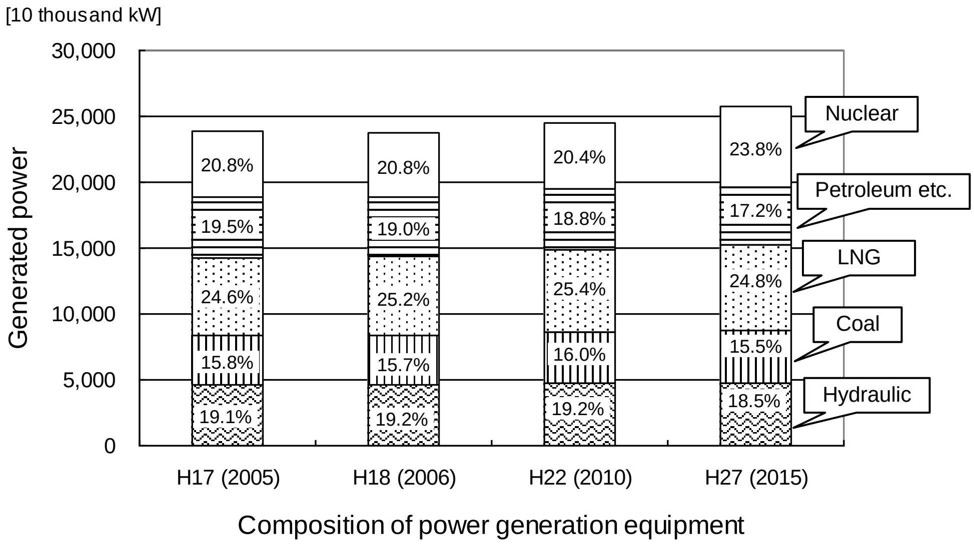

Fig.1: Current status and future prospect on composition of power generation equipment in Japan

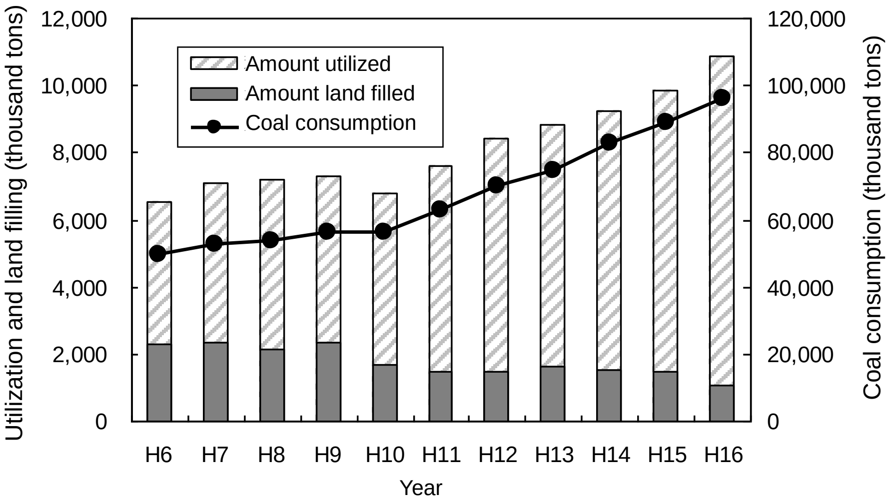

Fig.2: Changes in the amount of discharged coal ash in Japan

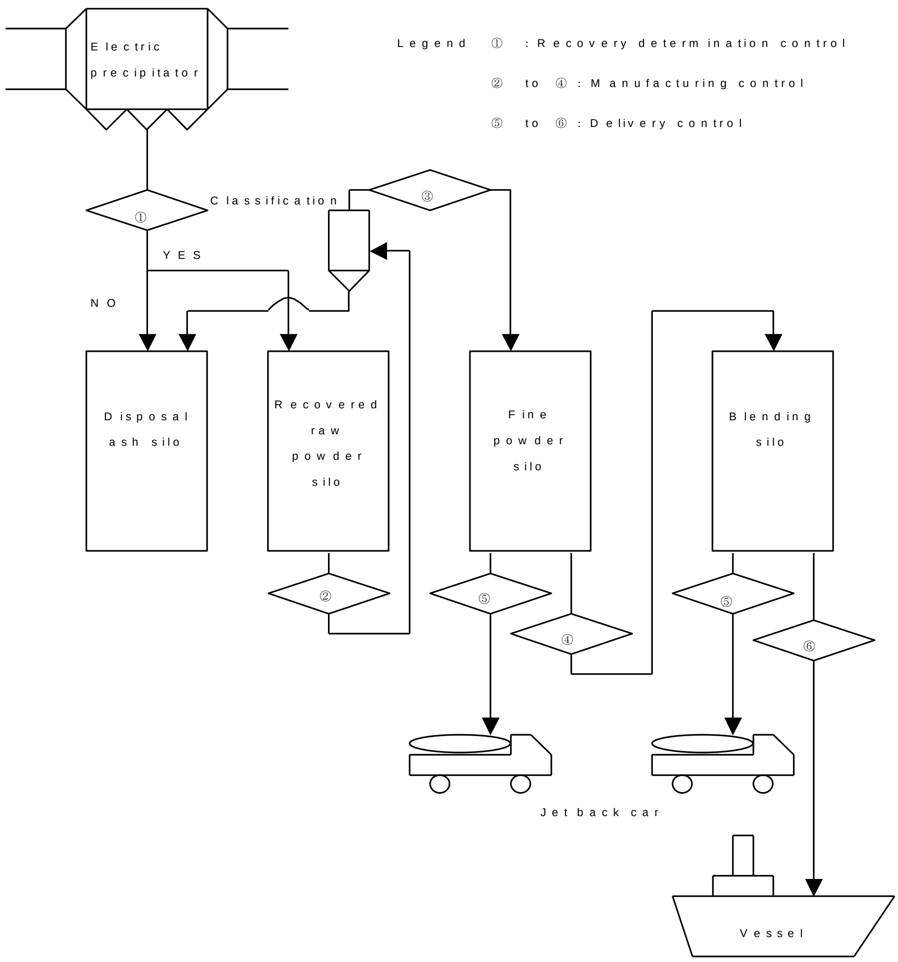

Fig.3: Quality control flow for fly ash

Table 1: Quality control items for "M" coal fired thermal power plant

		(1) Electric precipitator hopper outlet	(2) Recovered raw powder silo	(3) Classified fine powder	(4) Transfer	(5) Bulk loading	(6) Vessel loading
Test frequency		once per day	once per 6 hours	once per 6 hours	once per 6 hours	once per day	Before delivery Upon delivery
Ignition loss		○	○	○	○	○	○
Methylene blue adsorption number		○	○	○	○	○	○
Blaine value		○	○	○	○	○	○
Residue on 45 μm sieve				○		○	○
Density		○	○	○	○	○	○
Hygroscopic moisture					○	○	○
Flow value ratio						*○	○
Silicon dioxide						*○	○
Activity index	Material age 28 days					*○	○
	Material age 91 days					*○	○
Color tone		○					
Remarks		Mark * indicates monthly-composite-based quality testing					

3. JIS STANDARD FOR FLY ASH

The standard for fly ash for concrete use in Japan is specified in JIS A 6201, which was amended several times since its establishment, as summarized in Table 2 [4], and outlined below.

In 1958, a JIS standard (JIS A 6201) concerning the quality of fly ash as an admixture for concrete was first enacted.

This JIS standard was modified in 1974, when thermal power plants changed their major fuel from coal to heavy oil. In consideration of balance between supply and demand of fly ash, the standard figures were mitigated, that is, the standard figures on fineness were deregulated to a certain degree without detriment to the effect of fly ash. At the same time, standard figures on unit water volume ratio and compressive strength ratio were reviewed, and as for fineness, the regulation concerning residue on sieve was abolished, thus, only the regulation using Blaine value remains valid.

Amendment of this JIS standard in 1991 included changeover to the International System of Units (SI), and reviews of expressions on testing methods, representation of calculation formulas and symbols of reagents, while standard figures remain unchanged.

In 1996, the JIS standard was again revised with a view to preparing a user friendly environment on the quality of fly ash, wherein consistency of standard testing methods between other JIS standards and standards of foreign countries were incorporated. Major revisions in 1996 included introduction of flow value ratio instead of unit water volume ratio, introduction of activity index in place of compressive strength ratio and setting of mesh sieving method in the fineness standard.

The JIS A 6201 experienced a big revision in 1999, whose purpose was to extend the scope of effective applications of fly ash, including the establishment of four grades of quality in place of the original one grade, review of ignition loss testing method and temperature, and introduction of an alternative by directly measuring un-burnt carbon in the ignition loss. The conventional JIS type fly ash corresponds to the current JIS type II fly ash.

Table 2: History of amendment of JIS A 6201 for concrete-use fly ash

Item		JIS standard (1958)	JIS standard (1974)	JIS standard (1996)	JIS standard (1999)			
					Type I	Type II	Type III	Type IV
Ignition loss(%)		5 or less	5 or less	5.0 or less	3.0 or less	5.0 or less	8.0 or less	5.0 or less
Fineness	Residue on 45 μm sieve (mesh sieving method: %)	25 or less	–	40 or less	10 or less	40 or less	40 or less	70 or less
	Specific surface area(cm^2/g) (Blaine method)	2700 or over	2400 or over	2400 or over	5000 or over	2500 or over	2500 or over	1500 or over
Unit water volume ratio(%)		100 or less	102 or less					
Flow value ratio(%)				92 or over	105 or over	95 or over	85 or over	75 or over
Compressive strength ratio(%)	Material age 28 days	63 or over	60 or over					
	Material age 91 days	80 or over	70 or over					
Activity index(%)	Material age 28 days			80 or over	90 or over	80 or over	80 or over	60 or over
	Material age 91 days			90 or over	100 or over	90 or over	90 or over	70 or over
Density(g/cm^3)(specific gravity)		1.95 or over	1.95 or over	1.95 or over	1.95 or over			
Silicon dioxide: SiO_2(%)		45 or over	45 or over	45.0 or over	45.0 or over			
Hygroscopic moisture(%)		1 or less	1 or less	1.0 or less	1.0 or less			
Homogeneity in quality: Not to exceed values of submitted samples	Blaine method(cm^2/g)	±450 or over	±450 or over	±450 or over	±450 or over			
	Mesh sieving method(%)			±5 or over	±5 or over			
	Unit water volume ratio(%)	±5 or over	±5 or over					

4. QUALITY DISTRIBUTION OF JIS TYPE FLY ASH

From nationwide coal fired thermal power plants (24 power plants in all), the test reports on JIS type II fly ash for about two years (April 2001 to March 2003: about 450 data) were collected that have been prepared in accordance with the quality control procedures described in Chapter 2. Based on statistical treatment of these data, investigation and examination were conducted on the quality distribution of JIS type II fly ash as described in this Chapter.

4.1 Distribution of ignition loss

Figure 4 shows a histogram of ignition losses.
As illustrated in Fig.4, nearly all the ignition loss values are well below 3%, with 1 to 2% predominant, while the corresponding JIS standard (type II) specifies ignition losses to be 5% or less.

Besides the magnitude of ignition loss values, stabilized quality of fly ash at the time of delivery is also an important parameter. According to the data collected and investigated in this research, each power plant has its own trend in the magnitude of ignition loss values, with variations that are characterized in terms of standard deviation of about 0.3 to 0.5.

4.2 Distribution of SiO_2 content

Figure 5 shows a histogram of SiO_2 values. The corresponding JIS standard (type II) specifies SiO_2 content to be 45% or more, while in case of these actual data, the mean value is 59%, and 70% of the data concentrate around SiO_2 content of 55% to 65%.

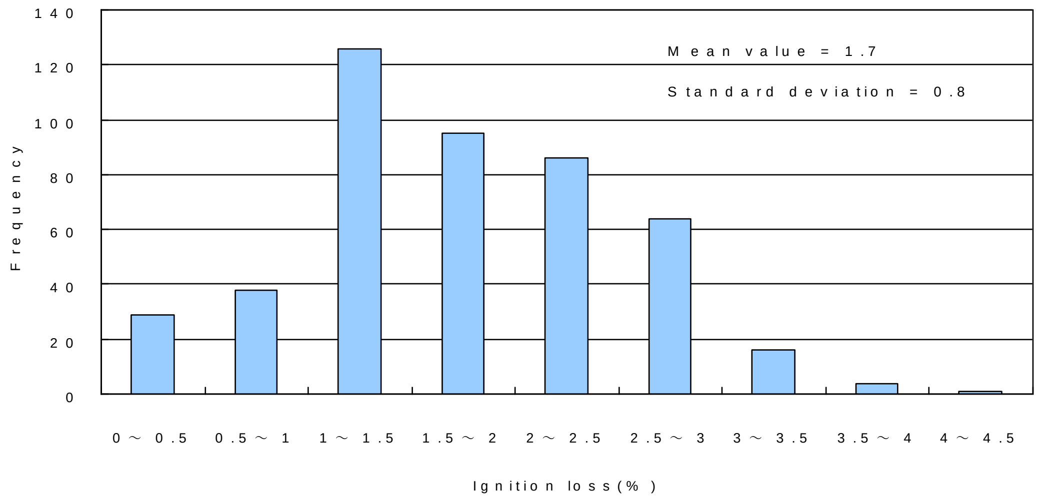

Fig.4: Distribution of ignition loss

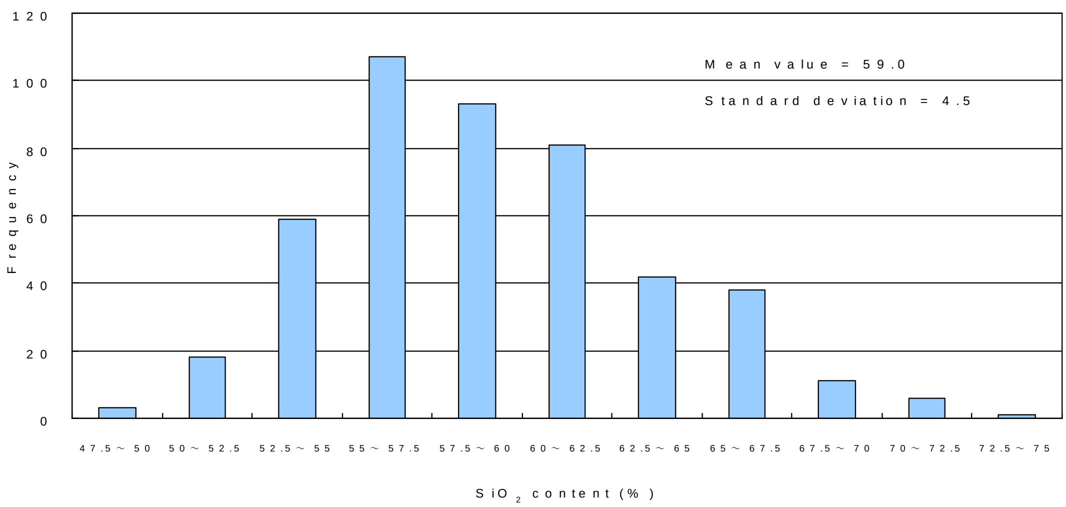

Fig.5: Distribution of SiO_2 content

4.3 Distribution of Blaine value

Figure 6 shows a histogram of Blaine values. The corresponding JIS standard for type II specifies Blaine values to be 2,500 cm^2/g or more, while most of the values for actual data in Fig 6 are 3,000 cm^2/g or more, with two peaks around 3,400 to 3,600 cm^2/g and around 3,800 to 4,000 cm^2/g. This is explained by the fact that each power plant has established its own quality standard for Blaine values. The overall mean for Blaine value is 3,800 cm^2/g. In this case, standard deviation has become large, which is considered attributable to the fact that statistical treatment has been applied by the gross to the data for all nationwide power plants. Standard deviations of Blaine values for each power plant varies from plant to plant within rages of 90 to 350 cm^2/g.

In most transactions, however, fly ash is supplied from a certain specified power plant to a concrete manufacturer, thus, actual variations in Blaine values are considered to be far smaller.

4.4 Distribution of flow value ratio

Figure 7 shows a histogram of flow value ratios. The corresponding JIS standard for type II specifies flow value ratios to be 95% or more, while Fig.7 shows the mean value of 106%, and mostly over 100%.

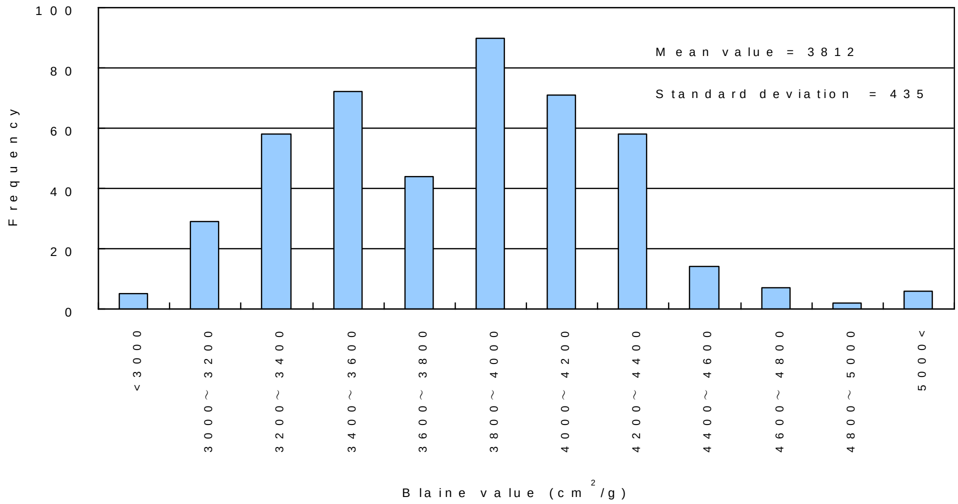

Fig.6: Distribution of Blaine value

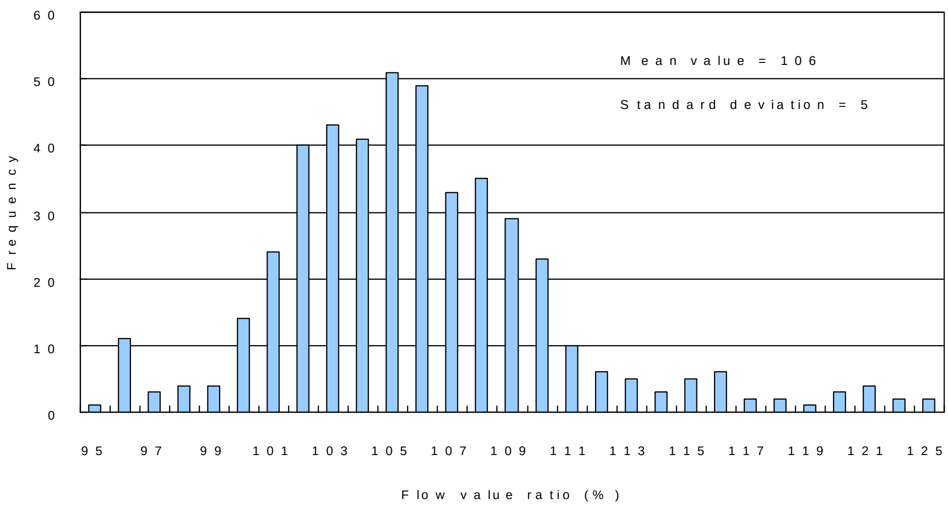

Fig.7: Distribution of flow value ratio

4.5 Distribution of activity index

Figures 8 and 9 show histograms of activity index for fly ash with material age of 28 days and 91 days respectively. The corresponding JIS standard for type II specifies activity index of 80% or over, and 90% or over for fly ash with material age of 28 days and 91 days respectively.

It is observed from Fig.8 that the mean value of activity index for fly ash with material age of 28 days is 84%, with more than 50% of all the data concentrating in a range of 80 to 83%. In Fig.9, the mean value for fly ash with material age of 91 days is 97%, with a distribution fairly close to that of a normal distribution.

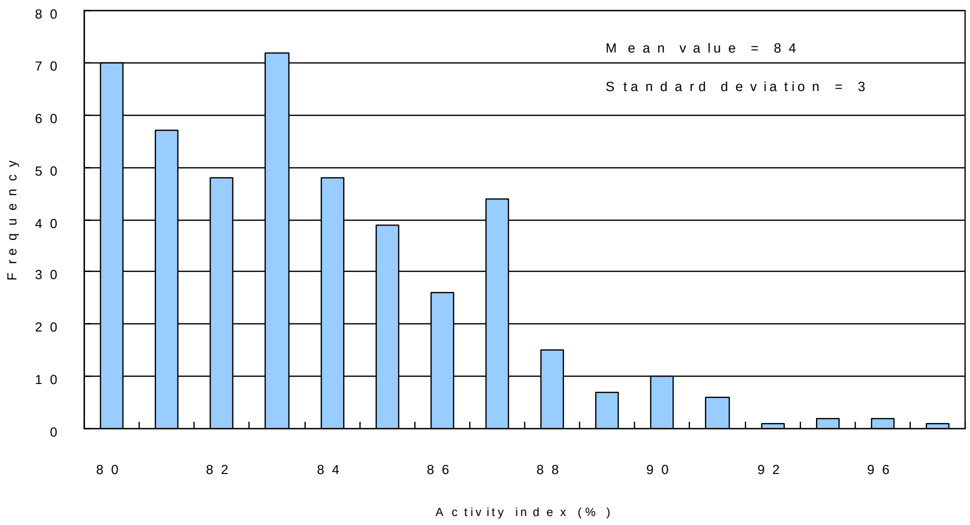

Fig.8: Activity index for fly ash with material age of 28 days

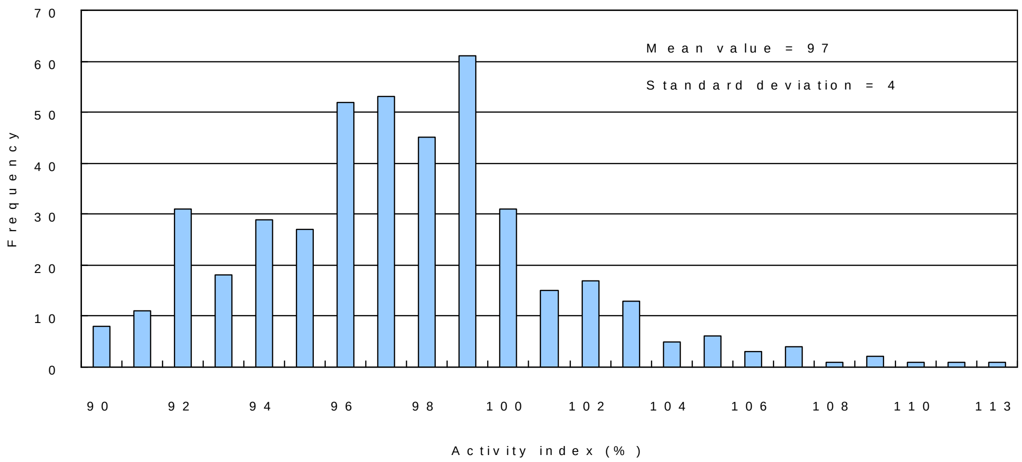

Fig.9: Activity index for fly ash with material age of 91 days

5. SUMMARY

Following are the conclusions of the paper on this research work.

(1) As for the quality distribution of JIS type fly ash (type II) that is delivered, a nationwide scale of data was collected from coal fired thermal power plants, which has provided information that the quality distributions fall within a certain range despite a large amount of gathered data.

(2) About 90% of coal ash discharged in Japan is fly ash, with the remaining about 10% being clinker ash. Among various technologies that are being developed for effective use of fly ash, the use as an admixture for concrete is considered the most effective one from the viewpoint of consuming a large amount of fly ash and of reducing the amount of CO_2 emission.

(3) Specification of fly ash for concrete use in Japan is stipulated in the JIS standard (JIS A 6201), which was amended several times since its establishment. In 1999, the JIS A 6201 experienced a big revision, whose purpose was to extend the scope of effective applications of fly ash, where a major change was the establishment of four grades of quality in place of the original one grade. Thus, the conventional JIS type fly ash corresponds to the current JIS type II fly ash. Most of fly ash currently available on the market is this type II fly ash.

(4) From nationwide coal fired thermal power plants (24 power plants in all), a large amount of data (about 450 data) on JIS type II fly ash for about two years (from April 2001 to March 2003) were collected. Based on statistical treatment of these data, investigation and examination were performed on the quality distribution of JIS type II fly ash as described below.

1) The quality distribution of ignition losses shows that a majority of data are in a range of 1 to 2%, mostly below 3%, with a mean value of 1.7%.

2) The quality distribution of Blaine values indicate that they are distributed in a range exceeding nearly 3,000 cm^2/g, with a mean value of about 3,800 cm^2/g.

3) In the quality distribution of flow value ratios, the data are distributed in a range exceeding nearly 100%, with a mean value of 106%.

4) In the quality distribution of active index for fly ash with material age of 28 days, nearly half the data fall in a range between 80% and 83%, with a mean value of 84%. In case of material age of 91 days, the distribution takes a form similar to that of a normal distribution, with a mean value of 97%. Judging from the quality distribution of active index for material age of 28 days, the standard value for this case seems to be set at a substantially severe level.

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