Adsorption Potentials of Coal Ash Associated with Geoenvironmental Problems

(地盤環境問題に関連する石炭灰の吸着特性について)

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Abstract: As one of the main industrial wastes in the world especially in Japan, coal ash has become a real problem when talking about the lack of disposal sites. Accordingly, based on this experimental study the physical characteristics of coal ash was evaluated together with it's chemical ability if used as an adsorbent or a filter layer beneath all the structures where in the chemical pollution danger is expected. Regarding the geotectonical aspect, permeability and compaction tests were carried out showing that, the coal ash is a very good material when used as fill material due to it's low permeability and the non existence of the optimum moisture point on the water content-dry density curve. Three major chemical analyses were carried out namely, pH test, high performance liquid chromatography (HPLC) and ultraviolet analysis. All of these tests have indicated that coal ash is applicable as a filter material in reducing the effect of the harmful organic matters such as benzene.

Key words: Adsorption, Organic Chemicals, Hydraulic Conductivity, Polarity

1. Introduction

Management of coal ash is considered one of the main issues from the point of view of environmental engineering due to the lack of disposal sites. In Japan about 20% of the electrical power is generated by coal thermal power plants. Furthermore , the number of these coal thermal power plants is expected to increase in the coming century yielding about 10,000 Gg of coal ash every year. Now, even though there is a big amount of coal ash used in cement manufacturing industry, there is a real need to find a way to utilize this huge amount of coal ash wastes. Geotechnical engineering has found its way to make this material applicable in some areas of earth works (Huang and Lovell, 1993 ; Tanabashi et al, 1996). In a column study provided by (Rael et al, 1995) a successful attempt was done to reduce the concentration of benzene of the ground water by using powder-activated carbon (PAC). PAC has also been used in water treatment , taste, odor etc., for more than 50 years (Clark and Lykins, 1989). Rice-husk ash (RHA) was also used as an adsorbent of Hg(II) from effluent solutions (Taiwari et al, 1995). Due to the high cost of PAC the authors have carried out a set of mechanical and chemical analyses in order to evaluate the efficiency of coal ash as an adsorbent medium. The result of the compaction test indicates that coal ash may be considered a suitable material for pavements and earth fill materials due to its linear behavior and its low incompressibility. Permeability coefficient also was found to be comparatively low 9.06×10^{-5} cm/s compared with other kinds of soil. This has led to the idea of using coal ash as an adsorbent or filter layer beneath all kinds of structures that manufacture or deal with oil products or harmful chemicals. Results of this study indicate the efficiency of coal ash as an adsorbent of some kinds of organic matters involved in any chemical materials. The coal ash used in this research with its chemical composition as shown in Table 1 was obtained from Kyushu Electric, Omura City, Nagasaki Prefecture. It has a particle density of 2.05 g/cm^3, maximum grain size of about 2 mm, uniformity coefficient of 2. The gradation curve of coal ash used is shown in Fig. 1.

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Table 1 Chemical components of coal ash
(After Kyushu Electric Co.).

Compound	(%)
SiO_2	62.1
Fe_2O_3	4.20
Al_2O_3	22.45
Ca O	1.80
Mg O	1.28
$Na O_2$	1.65
K_2O	2.22
$S O_3$	0.22
Fe O	-----
L. O. I	3.74

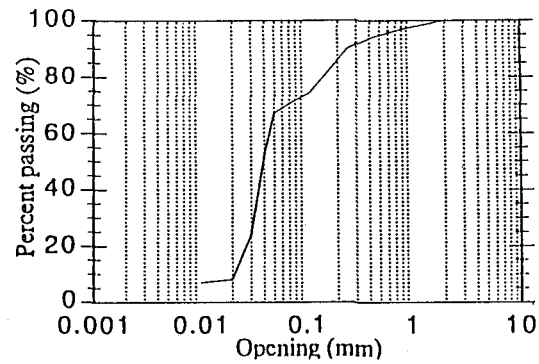

Fig. 1 Gradation curve of coal ash.

2. Materials and Methods

The ability of coal ash as an adsorbent of organic compounds was studied by two different methods, UV spectroscopy using benzene as an organic compound and HPLC by using an amino acid Lysine as an analyte. For this purpose, a sample of coal ash was obtained from a coal thermal power plant in Omura City, Nagasaki Prefecture, Japan. About 200g of this sample was washed with water. Washing with water is considered very important step because the coal ash is usually compacted in the field at specific water content a side from getting rid of all the water soluble substances which may yield any positive errors. Samples for UV spectroscopy were prepared by using three 15 cm in length and 1.5 cm in diameter glass test tubes with a hole punched at the bottom of each test tube. The coal ash was compacted inside these tubes by using a glass rod having less diameter than the test tube. The degree of compaction was achieved by filling the pre-determined volume by the exact weight. The height of the coal ash inside the tube was 3, 6, and 9cm at a density of 1.25gm/cm^3 and at water content of about 20%. This was followed by washing the coal ash packed test tubes with water for the HPLC and with methanol for the UV spectroscopy. The purpose of washing with methanol was to use the outflow as the blank (reference point) sample in the UV analysis while washing with water for the HPLC analysis since the Lysine was dissolved in water. Finally 10ml of a methanolic solution of benzene 0.01% (v/v) was allowed to pass through the three prepared test tubes for a period of 12 hours and then the outflow was collected and the concentration of benzene was determined by UV spectroscopy. For HPLC, the same procedure was carried out as mentioned above with the only difference of using an aqueous solution of 1g/1000ml amino acid Lysine as an organic compound instead of benzene with no need for washing coal ash columns with methanol. For pH value analysis the same procedure was followed by passing of ordinary water, diluted Nitric acid, and Sulfuric acid through the coal ash packed columns. The scheme of the experiments is shown in Fig. 2.

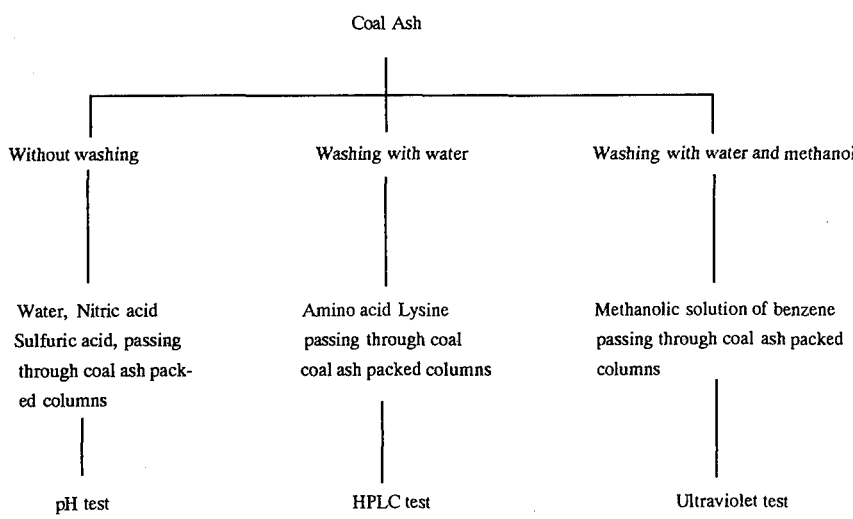

Fig. 2 Experiment schematic diagram.

3. Results and Discussion

3. 1 Compaction and unconfined compression tests

Compaction test was carried out by using standard Proctor test apparatus. Test results clearly indicate that coal ash is a very suitable material for earth work. As shown in Fig. 3 optimum moisture content does not appear clearly in this curve which means that coal ash can maintain its density at variable moisture content. Furthermore a set of unconfined compression tests were performed to check its compressive strength at different water contents. The axial stress is mostly the same at a water content of 10-15% while it slightly decreases beyond that as shown in Fig. 4.

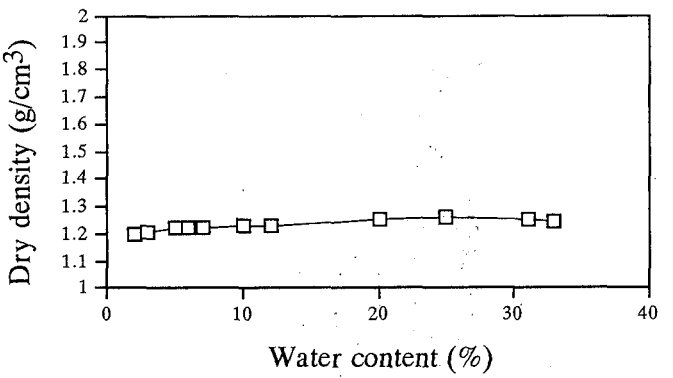

Fig. 3 Water content-dry density curve.

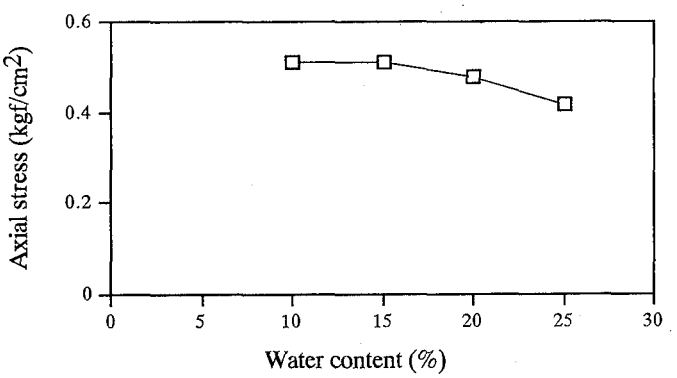

Fig. 4 Unconfined compression test results of coal ash.

3. 2 Chemical Properties of Coal Ash

(1) *Adsorption of benzene*

One of the most common used methods of quantitative analysis is to measure the absorption of ultraviolet (UV) radiation by species in solutions. This technique is based on the principle that all atoms and molecules are able to absorb energy from an electromagnetic radiation (light) and the kind and amount of radiation absorbed depend on the structure of the molecule

and its concentration. The machine used in this research is JASCO UV/VIS Spectrophotometer RF-540. In this research, the ability of coal ash to adsorb and retain organic compounds was evaluated by passing of the methanalic solution of benzene at a concentration of 0.01% (v/v) through a glass columns with a hole punched at the bottom and packed with the coal ash. Since the benzene molecule absorbs UV light at a wavelength of 255nm (Connors, 1986), it was used to monitor the concentration of benzene of the outflow of three coal ash packed columns. The coal ash was washed with methanol and the outflow of that was used as a blank in the experiment. Results indicate that the concentration of benzene as an organic material was reduced to about one-sixth. Figure 5 shows the relationship between the column height and the absorbance. In this experiment and under these conditions the effective optimum length of the column seems to be between 6-9 cm since the change in absorbance is not so significant beyond 6 cm. These results suggest that the coal ash may be considered as a promising material, since it has the ability to retain and to reduce the concentration of some organic compounds (benzene) for many times. Figure 6 shows the results of using the coal ash for many times. This result indicates that the coal ash has the capacity of retaining the benzene more than one time.

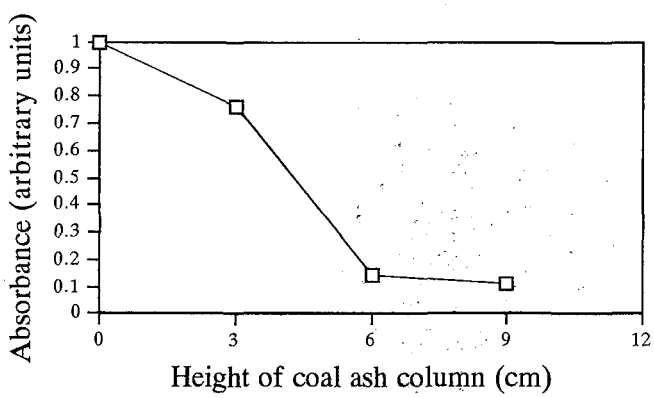

Fig. 5 Relationship between the height of coal ash column and the relative absorbance of benzene.

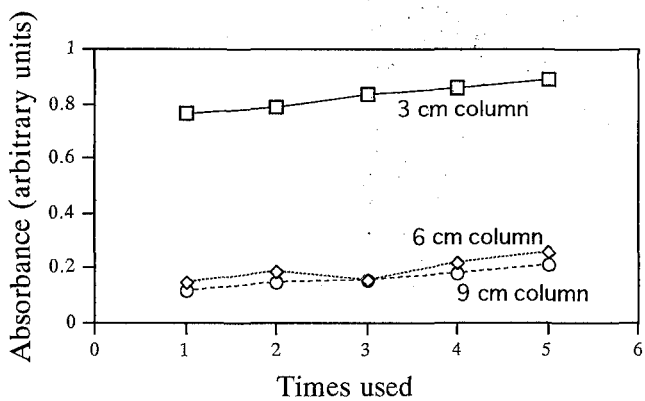

Fig. 6 Adsorption capability of coal ash when used for more than one time (i.e. Reusability).

(2) *Adsorption of Lysine*

Results of UV spectroscopy determination of benzene concentration suggest that the coal ash is able to adsorb the non-polar organic compounds such as benzene. In order to investigate the coal ash ability to adsorb other organic compounds which possess ionizable groups like amino acid Lysine having both the carboxyl and the amino group, HPLC as one of the most sophisticated separation techniques was used in this research to separate the amino acid Lysine from other substances found in the outflow of the column to determine its concentration .The machine used in this experiment was JLC-300 Fully

Automated Liquid Chromatograph. The results show that the Lysine amino acid was retained on the coal ash since there was a noticeable decrease in the peak area (which represents the concentration of Lysine) as the thickness of the coal ash increased. The concentration of Lysine was reduced to one-fifth of its original value as shown in Fig. 7. It also suggests that the coal ash has the ability to adsorb and retain any other organic compounds which possess ionizable groups. As shown in Fig. 7, the column height of about 6 cm is the optimum in this experiment since there was no significant decrease in the peak height beyond it.

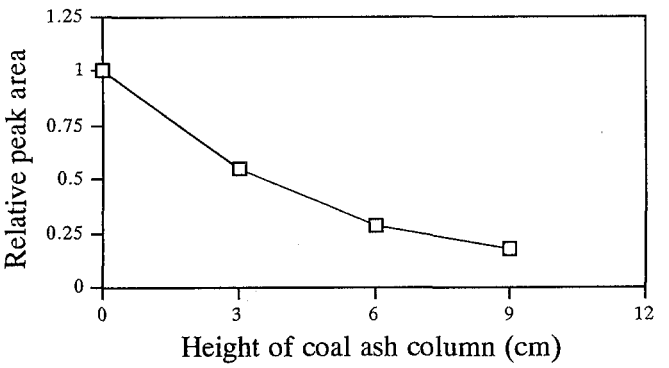

Fig. 7 Relationship between coal ash column height and concentration of lysine.

(3) *Neutralization of Acids*

Concentration of Hydrogen ion H^+ of water is considered one among some very important characteristics which simply indicate whether the water is drinkable or not. This is due to the fact that bacteria cannot live in any media with pH more than 8.3. As shown in Fig. 8 the coal ash is capable of raising the pH of water up to 8.3 creating inconvenient medium for bacterial growth. Another two chemical materials were also used namely, Nitric acid and Sulfuric acid with a pH of 1.0 and 1.4 respectively. After passing through the coal ash columns the pH was changed remarkably showing that the coal ash is a suitable material if used in the treatment of acid materials before reaching the final disposal site. Furthermore there was no deficiency in its function as neutralizing agent when used for so many times. To confirm this fact a series of tests were done by passing of each acid using a single coal ash column for 4 consecutive times. There was no significant change of pH of all the acids used.

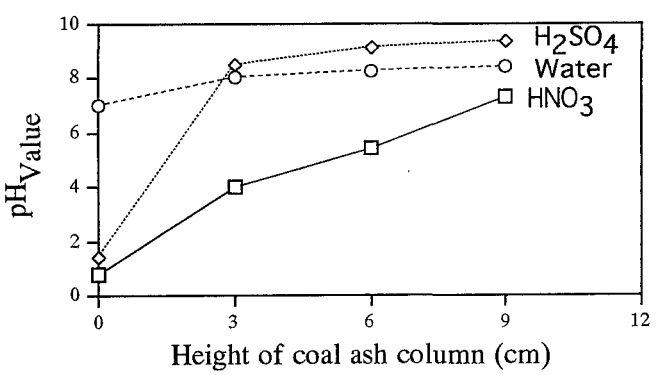

Fig. 8 Effect of coal ash on the acidity of ordinary water and some other acids.

4. Proposed Fields of Application

Due to the availability of huge amounts of coal ash and as proved in this research, coal ash may be used in the field of geotechnical engineering for many purposes which can be summarized as:

a) Coal ash is considered a very applicable material if used as an adsorbent or filter layer beneath all kind of structures that deal directly or indirectly with oil or acid chemical materials such as oil refineries and gasoline stands.

b) Coal ash is very applicable as an earth fill material in building embankments or as subgrade materials. It can maintain its strength at variable water contents.

c) For agricultural purposes, coal ash is strongly recommended to be used or mixed with soils in the areas where acid rain is encountered.

d) As there is no bacteria can live or grow in any media with pH higher than 8.2, coal ash can be used for alternative purposes such as treatment of dam waters and as a fertilizer in the field of agriculture.

5. Conclusions

Based on this investigation, it is apparent that coal ash could be successfully used as an adsorbent or a filter layer beneath structures involved in oil or chemical industries. An interesting conclusion is obtained from the result of the Ultraviolet test which shows that coal ash has the capability of retaining benzene and reducing its concentration to about one-sixth. Its adsorbtion was checked once more by using another kind of organic compounds such as Lysine amino acid and the HPLC technique which serves as a confirmation of its efficiency. Mechanical properties of coal ash were studied also which show its applicability as a fill material due to its low compressibility and low coefficient of permeability. Its medium permeability is considered as an important characteristics which helps in giving time for the organic materials to be well retained and adsorbed. A main conclusion also can be drawn from the results of the pH analysis which show that coal ash has a remarkable effect in changing the acid media into alkali media.

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References

Clark, R. M. and Lykins Jr., B. W. (1989), Granular Activated Carbon: Design, Operation, and Cost. Lewis Publishers, Inc., Chelsea, Michigan.

Connors, K. A. (1986), A text Book of Pharmaceutical Analysis, 3rd edition, John Wiley & Sons, p. 199.

Huang, W. H. and Lovell, C. W. (1993), Use of Bottom Ashes and Slags in Highway Construction. 4th International Symposium on the Reclamation, Treatment and Utilization of Coal Mining Wastes, Karakow, Poland, Vol.1, pp. 318-321.

Rael, J. , Shelton, S. and Dayaye, R. (1995), Permeable Barriers to Remove Benzene: Candidate Media Evaluation, Journal of Environmental Engineering, Vol. 121, No. 5, pp. 1-3.

Taiwari, D. P. , Singh, D. K. and Saksena, D. N. (1995). Hg(ll) Adsorption from Aqueous Solution Using Rice-Husk Ash, Journal of Environmental Engineering, Vol. 121, No. 6, pp. 1-2.

Tanabashi, Y., Gotoh, K. , Itoh, H. , Miyagawa, H. , and Nakamura, M. (1996) , An Experimental Study on Effective Utilization of Coal Fly Ash and EPS Wastes as a Light Weight Ground Material, International Clean Coal Technology Symposium On Coal Ash Utilization, Tokyo, Japan, pp. 248.