The Effect of Coal Ash on the Strength Parameters of Clay

by

Monther Abdelhadi* and Keinosuke Gotoh**

Coal ash is considered one of the most serious challenges to the 21st century due to its huge accumulation inside or around the power generating plants. From this point of view the authors have carried out a series of tests in an attempt to improve the engineering behavior of Ariake clay by using coal ash. Ariake clay was mixed with different amounts of coal ash within the range of 3–12% of the clay wet weight. These tests are sedimentation test, tri-axial compression test, Oedometer test, and consistency limits test. These tests are considered very important in determining the behavior of the treated clay as an approach to further application of coal ash in soft ground improvement. As a result of this it is apparent that coal ash can be successfully used in stabilizing clays

1. Introduction

Recently, coal is considered as the main energy source second to petroleum due to its less effect on the environment and its relatively low cost. Due to the public resistance of nuclear power plants large amounts of about 10, 000 Gg of coal ash are expected within the next century[1]. Accordingly, large scale utilization has become an important issue to be solved. At the mean time coal ash is being successfully used in many fields such as cement manufacturing and land fill material[2]. The amount being used is still one half of the produced amount[3]. Now a days lime-coal ash is being used in soil stabilization by means of injections in order to minimize settlement of soft ground[4].

In this research an attempt was done aiming to the evaluation of coal ash potentials and performance if mixed with soft clay where high water content is encountered. Ariake clay with a high water content was used for the above mentioned purposes. The effect of coal ash on the sedimentation, compressibility, shear strength and consistency of the clay was carefully studied and analyzed.

Received on October 28, 1997

*Graduate School of Marine Science and Engineering.

**Department of Civil Engineering.

2. Materials Properties

2.1 Ariake clay

Ariake clay with its dark blue color is considered as a very sensitive clay spreaded along the west coast of Japan around the Ariake sea.

Its water content is higher than its liquid limit means that the clay has the potential to become liquid when disturbed. It has a specific gravity of 2.65, liquidity index of about 1–2, plasticity index of about 65 % and natural water content of 130%. Ariake clay is a soft clay characterized by the low values of unconfined compressive strength and it is considered a sensitive one due to the loss of its strength when disturbed.

2.2 Coal ash

The coal ash used in this study was obtained from Kyushu Electric Co., Omura power plant, Nagasaki Prefecture. It has a specific gravity of 2.05. The chemical composition of this coal ash is shown in Table 1 in which Silicon Dioxide (Silica) and Aluminum Oxide (Alumina) are dominants. Regarding its geotechnical characteristics, its maximum grain size is 2 mm with a uniformity coefficient of 2. As shown in Fig. 1 the coal ash is considered as poorly graded ash. The compaction curve of coal ash as shown in Fig. 2 is mostly flat distinguished by the non-existence of the optimum moisture content which indicates that the degree of compaction is not much sensitive to water content. This also was confirmed by the unconfined compression test of coal ash at various water contents. As shown in Fig. 3 the axial stress of coal ash does not change significantly over a wide range of water content.

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
CaO	1.80
MgO	1.28
NaO_2	1.65
K_2O	2.22
SO_3	0.22
FeO	—
L. O. I	3.74

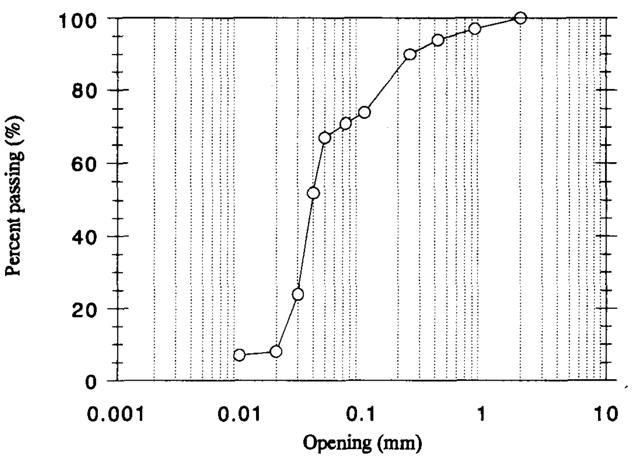

Fig. 1 Grain size disribution of coal ash.

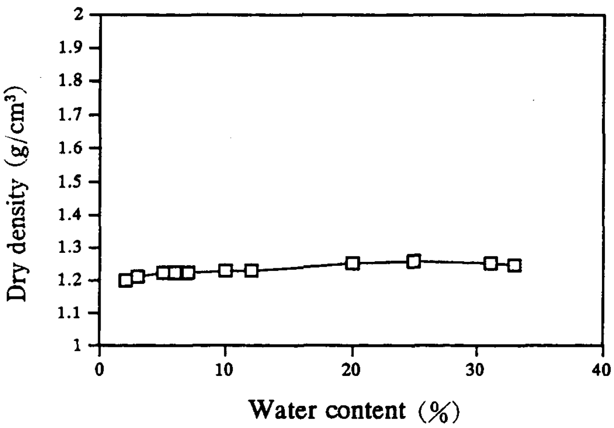

Fig. 2 Water content-dry density curve of coal ash.

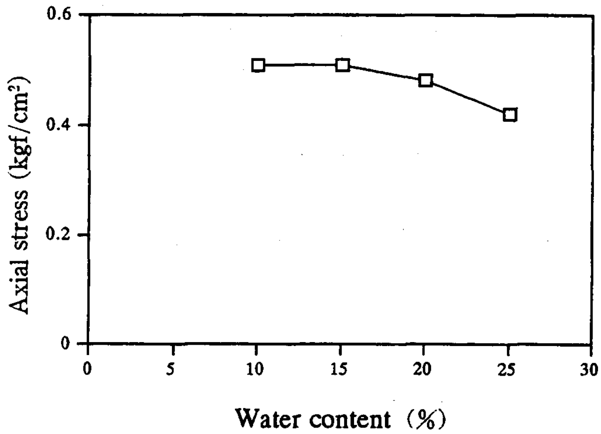

Fig. 3 Unconfined compression test results of coal ash at variable water content.

3. Testing Procedure

The clay sample was brought from the mouth of Honmyo river at the eastern part of Nagasaki City as shown in Fig. 4 and placed in a well closed plastic container. Its water content and atterberg's limits were immediately determined. This was followed by adding water and mixing until the water content of the sample was raised to about 320%. For the sedimentation test 250g of the prepared clay sample was thoroughly mixed with water by using a small mixer until the whole volume was 1000 ml and then placed inside a sedimentation tube for 24 hours. To apply the coal ash the same procedure was followed but by adding different percentages of 3, 6, 9 and 12% of coal ash at each trial. All these test tubes were left for 24 hours. For the other tests, Tri-axial, oedometer and consistency limits 4 samples were prepared by mixing each sample with 3, 6, 9 and 12% of coal ash respectively. In tri-axial compression tests all the samples were preconsolidated at 0.2 kgf/cm^2 for a period of one week.

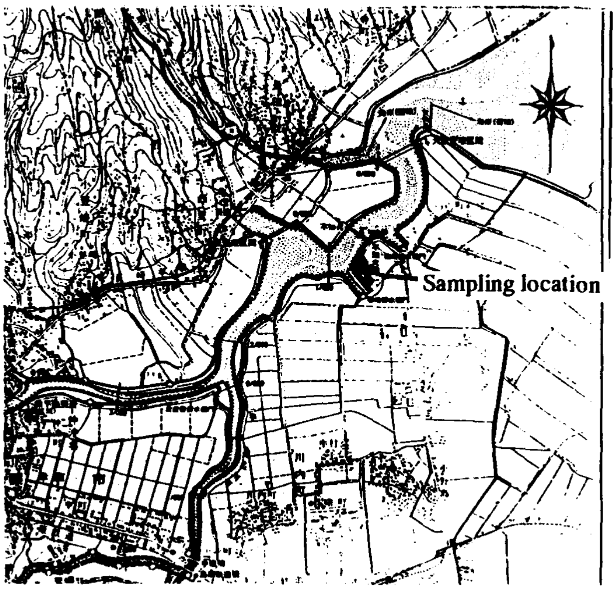

Fig. 4 Sampling location of Ariake clay.

4 . Results and discussions

4 . 1 Sedimentation test

In the sedimentation test the samples mixed with different percentages of coal ash were compared with the clay sample by leaving the 5 test tubes for 24 hours. It was observed that the depth of the sedimented layer in case of using the coal ash together with the clay is less than it by using clay only. This suggests that there was a kind of attraction forces created between clay and coal ash particles. This attraction forces may have led to a crumble heavy structure that easily settle down. This is considered a good indication of denser mix. Photo 1 shows the result of ordinary clay sample compared with sample of the same caly mixed with 9% coal ash in which the difference in the thickness of the two layers was about 25 mm.

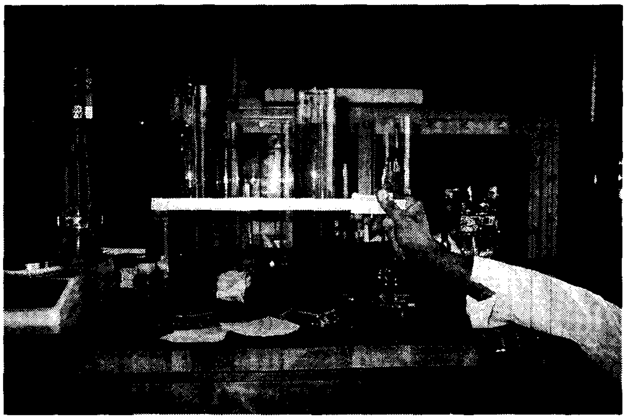

Photo 1 Result of sedimentation test.

4 . 2 Consistency limits

This test was performed in order to study the effect of mixing the clay with the coal ash on the consistency of the clay. Results of this test have showed that adding coal ash helps a lot in reducing the liquid limit and the plasticity index of the clay. As a demonstration of that mixing the clay with 12% of coal ash has reduced the plasticity index to about 12 from its original value of 65 for ordinary clay. On the other hand it has increased the plastic range of the clay by raising the plastic limit from 61% to about 81%. The complete results of atterberg limits are shown in Fig. 5.

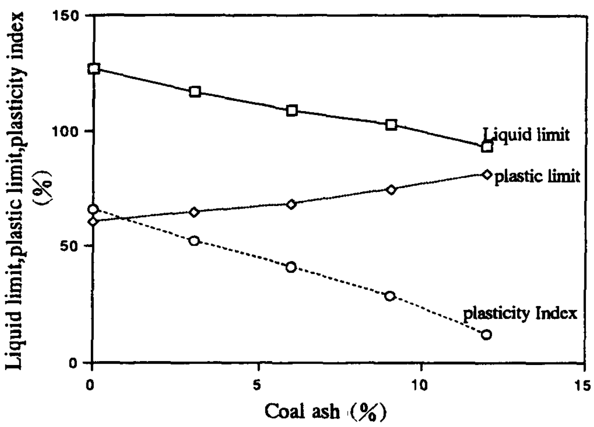

Fig. 5 Changes of the consistency limits of the clay at different percentages of coal ash.

4 . 3 Consolidation Test

A conventional oedometer tests were performed for the purpose of studying the consolidation behavior of the clay and clay mixed with coal ash. Results indicate that the general trend of the clay mixed with coal ash is low compressibility as can be observed in

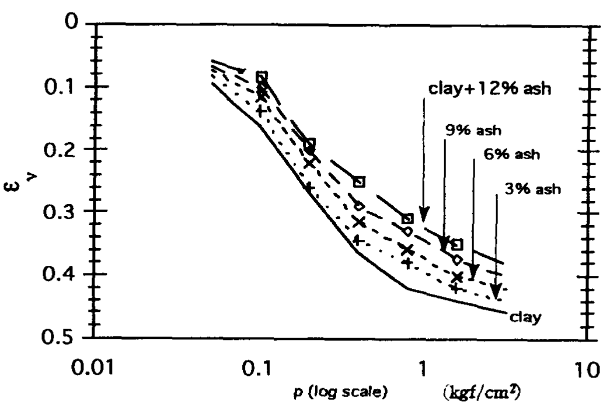

Fig. 6 Results of the consolidation tests of clay mixed with different amounts of coal ash.

Fig. 6. This low compressibility may due to the effect of coal ash which as previously confirmed that it has no optimum moisture content on the compaction curve. This result can be considered as a significant one if the shear strength of the coal ash samples is proved to be higher than ordinary clay.

4.4 Tri-axial compression test

For the Tri-axial compression test 4 samples were prepared at different amounts of coal ash within the range of 3–12%. These samples were pre-consolidated at a consolidation pressure of 0.2 kgf/cm^2 for one week. It was well observed that the undrained shear strength is proportional to the amount of coal ash added. The peak undrained shear strength of all the samples was obtained mostly at 15% axial strain. As can be seen in Table 2 the maximum value of the undrained shear strength was about 4 times of the ordinary clay.

Table 2 Undrained shear strength of clay mixed with different amounts of coal ash.

Mixing Ratio	Undrained shear strength (kgf/cm^2)
Clay only	0.057
Clay+3% coal ash	0.096
Clay+6% coal ash	0.120
Clay+9% coal ash	0.150
Clay+12% coal ash	0.200

5. Conclusions

Based on this study, it can be understood that coal ash can be used in soft ground stabilization due to its multi-functions such as the possessing of pozzolanic reaction with the passage of time, mostly constant dry density and insignificant change of compressive strength over a wide range of water content. Finally, coal ash is strongly recommended as grouting material for soft ground stabilization.

References

1) Tanabashi, Y., Gotoh, K., Itoh, H., Miyagawa, H., and Nakamura, M.: An Experimental Study on Effective Utilization of Coal Fly Ash and EPS Wastes as a Light Weight Ground Material, Proc. of International Clean Coal Technology Symposium on Coal Ash Utilization, Tokyo, Japan, pp. 248–260. 1996.

2) San Juan, G. M.: Essentials of Producing High Strength Concrete, Proc. of Fourth International Conference on Civil Engineering, Manila, Philippines, pp. 1–12. 1996.

3) Goto, K., and Shibata, T.: Coal Ash as Reclamation Material and Its Geotechnical Procedures For Improvement, Proceedings of the Second Int. Congress on Environmental Geotechnics, Osaka, Japan, pp. 715–720. 1996.

4) Joshi, R. C., and Nagaraj, T. S.: Fly Ash Utilization for Soil Improvement, Proc. of The Symposium on Environmental Geotechnics and Problematic Soils and Rocks, Bangok, pp. 15–24. 1987.