PARTICLE SIZE DEPENDENCY OF COAL FLY ASH AMENDMENT AND THE IMPACT OF SURFACE MODIFICATION ON SAND WATER RETENTION CAPACITY

O Mengzhu SONG1), Shenlei LIN1), Fumitake TAKAHASHI1)
1) Tokyo Institute of Technology

1. INTRODUCTION
Every year, huge amount of coal fly ash (FA) is accumulated without any recycles. This is a severe problem to both the society and the environment in particular in arid area because coal is a major power source. On the other hand, desertification is also a severe problem in arid areas. The purpose of this study is to recycle FA as a soil amendment material to improve water retention capacity of the soil. It can solve both FA management problem and desertification problem at the same time. In this study, the effect of raw fly ash amendment on water retention capacity (WRC) of sands would be discussed. The sand particle size effect will be practically focused on to explain FA amendment effect. In addition, the effect of the organic-treated coal fly ash amendment on water retention capacity will also be included. These results might give some useful hints on effective pretreatment of sands and FA.

2. MATERIALS AND METHODS

2.1 Sands, coal fly ash
Two kinds of sands named river sand (RS) and silica sand (SS) were used. In order to study the effect of raw-fly ash amendment on WRC of the sand and its particle size dependency, the sands were sieved into different size ranges. The size ranges of RS are 75-150 μm, 150-250 μm, 250-500 μm, 500-710 μm, 710 μm-1 mm, 1-2 mm, and larger than 2 mm. The size ranges of SS are 75-150 μm, 150-250 μm, and 250-500 μm. FA utilized in this study was taken from one coal-fired power plant in Japan.

2.2 Water retention capacity (WRC)
Physical water loss can be measured under a water-saturated condition which is usually controlled by gravity or pressure. In this way, the water holding capacity (WHC) of soil is usually measured. However, water saturation of soil is limited situation in arid areas, and temperature-driven evaporation is a main pathway of soil moisture loss. In this study, a new method was tested to evaluate water retention in soil under unsaturated condition by simple drying experiment1) This method can include the impact of temperature-driven evaporation on water loss. It is called as water retention capacity (WRC) in this study. The concept of WRC is illustrated in Figure 1. WRC was defined as the area of water retention curve. The WRC means water evaporation resistivity rather than available volumetric capacity for water in soil structure. Drying experiments were conducted at natural temperature and 40 °C. FA was mixed with dried sands at mixing ratios of 10, 20 and 30 wt%. Initial moisture content was 30 wt% for each sample. The weights of the samples were measured continuously at one hour interval to monitor water retention in the samples. The experiments were repeated three times to check experimental errors. One-sided Welch's t-test with 5% significance level was used to test the statistical significant differences of WRC among FA-amended samples.

2.3 Organic treated-FA amendments on WRC
Organic treatments of FA for textural modification were tested to investigate the impact on sand WRC. Two types of organic treatments were used in this study. They are polyacrylic acid (PAA) and polyacrylic acid with calcium chloride (PAA+CaCl2).100 g of 25 wt% polyacrylic acid solution was simply mixed with 400 g of raw FA, and the treated FA was dried at 105 °C. After drying, they were cooled, crushed softly, and then used in drying experiments. On the other hand, 200g of the polyacrylic acid treated-FA was mixed with 100ml of 0.5 mol/L calcium chloride and dried. After drying, they were cooled, crushed again, and then used in another set of drying experiments. Drying experiments of sand samples with two types of treated FA amendments were conducted at 40ºC and natural temperature.

2.4 Organic compound measurement
Organic compounds contained in sand samples were measured by the weight loss after thermal decomposition at 440 °C in a muffle furnace overnight. The measurements were repeated three times to check experimental errors.

3. RESULTS AND DISCUSSION

3.1 Effect of organic matters on size dependency of WRC
Results showed there was particle size dependency of sand on the WRC. The highest/lowest WRC appeared in certain range of particle size. One-sided Welch’s t-test suggested that the size dependency of raw FA amendment on WRC was regarded as significant in those cases even when experimental errors were taken into account. For example, in the case of RS at 40 ºC, statistically significant differences appears between the lowest WRC at size range of 500 μm-1 mm and the highest WRC at size range of 1-2 mm. SS also has significant differences between the lowest WRC at the size range of 75-150 μm and the highest WRC at the size range of 250-500 μm at both natural temperature and 40 °C. The size dependency of WRC also depends on temperature. Optimum size range for the highest WRC shifts to smaller or larger size range when drying temperature changes. Further experiment results of the organic compound measurements suggested that the size dependency could be partially

Fumitake Takahashi, Tokyo Institute of Technology
G5-13, 4259, Nagatsuta, Midori-ku, Yokohama, 226-0026 Japan
Tel: +81-45-924-5585 FAX: +81-45-924-5518 e-mail: takahashi.f.ai@m.titech.ac.jp
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explained by the difference of the weight ratios of organic matters in the different size ranges of sand. Positive or negative correlations were found between WRC and the weight ratio of organic matter (see Figure 2). The temperature effect on WRC can also be partially explained by the hydrophilic or hydrophobic character changes of organic matters at different temperature. For example, sodium salts of humic and fulvic acids, changed their hydration states at 5 to 90 °C. Graber et al. reported that fatty acid salts make soil more hydrophilic with temperature increase. However, there are other reports about aging treatment at constant temperature from 25 °C to 105 °C made organic matter more hydrophobic. Therefore, there are still some uncertainties about how the temperature exactly affects hydraulic properties of soil/sand organic matters.

3.2 Effect of raw/treated-FA amendment on sand WHC

From the result of t-test, it suggested that the effect of raw-FA amendment on sand WRC is much smaller than that of size effect. In most cases, raw-fly ash amendment gave no statistically significant impact on WRC. On the other hand, WRC differences among different size ranges were regarded as statistically significance in many cases. At natural temperature, the PAA-treated FA amendment had nearly no effect on the WRC. At 40°C, however, the treated FA amendment increased WRC of SS and RS when the mixing ratio was 20 wt% (See Figure 3). T-test suggested that 21% increase of SS WRC at 20% mixing ratio was statistically significant. On the other hand, the effect of PAA-treated FA amendment on RS WRC was usually not significantly positive in other mixing ratios. As a comparison, PAA+CaCl$_2$ treated-FA amendment on WRC was also tested, in hope to generate micro-porous structure on the surface of PAA treated-FA by adding Ca$^{2+}$. It was expected to serve as a water holding space to increase the WRC. However, the results were different from the expectation. At 40°C, it showed that the WRC of sand was mainly decreased by mixing with the PAA+CaCl$_2$-treated-FA. However, under the natural condition, the PAA+CaCl$_2$-treated-FA amendment slightly increased the WRC compared to the WRC of pure sand samples under the same condition. Therefore, it can be concluded that the temperature may have an important impact on hydraulic properties of PAA+CaCl$_2$-treated-FA. As summary, the PAA+CaCl$_2$-treated-FA amendment will not increase the WRC of the sand greatly. Therefore, other ways of the treatments of FA need to be explored in the future experiments.

4. CONCLUSION

The effects of FA amendment on WRC of sand with different size ranges were investigated. WRC of tested sand had particle size dependency regardless of raw FA amendment. The effect of sand particle size on WRC was much larger than raw FA amendment effect. It could be explained partially by organic matter concentration in sand fractions. When water loss via temperature-driven evaporation from sand is focused on, raw-FA amendment is not effective but organic matters are influential greatly. Organic modification of FA surface might be promising. Polyacrylic acid-treated FA amendment increased WRC of SS at 40°C when 20 wt% of treated FA was amended. However, there are some uncertainties about the temperature impact on the organic-treated FA. Further experiments need to be conducted to verify FA modification effect on WRC.

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REFERENCE


Figure 2. Correlation between WRC and weight ratio of organic matter of RS and SS in each size fraction under natural condition and at 40 °C.

Figure 3. The effect of PAA treated-FA amendment on WRC of SS [A1] and RS [B1] and PAA+CaCl$_2$ treated-FA amendment on WRC of SS [A2] and RS [B2].