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EFFECT OF CURING TIME AND MOISTURE CONTENT ON SWELLING POTENTIAL OF BOTTOM ASH-BENTONITE MIXTURES

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ABSTRACT

Over the last decade, there has been increased attention aimed toward the use of coal combustion products in geotechnical applications. Several studies have been completed to determine the properties of bottom ash from burning of pulverized coal, amended with admixtures such as bentonite, clay, and lime. Because of significant volume change characteristics of bentonite, soils or similar granular materials amended with it should be evaluated for their swelling behavior. A study recently conducted on bottom ash has shown that strength and stiffness characteristics of bottom ash amended with bentonite change significantly with the curing of the mixture. Therefore, this study was initiated to investigate the effect of curing and moisture content on the swelling characteristics of pulverized coal combustion bottom ash amended with bentonite. Bottom ash samples containing 20 percent bentonite and prepared at 16 and 18 percent initial moisture content were tested in this investigation. Results presented show that curing and initial moisture content of the mixtures have significant effect on the swelling potential of bottom ash-bentonite mixtures.

Key Words: Bottom ash, coal combustion, curing, swelling

INTRODUCTION

The use of coal in power generating plants around the world results in the production of an overwhelming amount of coal combustion products (CCPs). These products must be disposed off in an acceptable and environmentally safe manner. Currently, most of these CCPs are disposed off in landfills and/or ash ponds. Although, only 10% of the total CCP produced in the United States of America were being used in various applications in early 90s (Dube 1994), the utilization of CCPs increased to approximately 29 percent in the year 2000 and to 33 percent in the year 2001(Kalyoncu 2003; Kelly and Kalyoncu 2002). In the year 2001, only 36.87 Mt (metric tons) of CCPs were used whereas about 107 Mt were produced (Kalyoncu 2003). Because of strict environmental regulations in place and limited availability of land to build landfills and ash ponds, there is immediate need to develop new, environmentally safe, and cost effective applications of CCPs. Currently, most of the CCPs used are in the construction applications including use in grout, concrete, road base, sub base material, and mining applications. Utilization of CCPs in geotechnical applications is still very limited.

The bottom ash produced from the pulverized coal is a dark gray, granular, and porous material which has particle size distibution similar to natural sand. Natural sand is commonly used in the construction industry in place of cohesive soils by adding admixtures to amend its properties. Since most scientists and researchers have come to the conclusion that bottom ash from PCC power plants displays physical properties similar to that of natural sands, some researchers have studied the possibility of use of PCC bottom ash in various construction applications after modifying its properties by mixing it with various admixtures, e.g., Das et al. (1978), Huang and Lovell (1990 and 1993), Kayabali and Bulus (2000), Kumar and Stewart (2003a, b), Kumar and Vaddu (2003), and Seals (1972).

Sodium bentonite is a common type of clay frequently used to modify soil properties. Sodium bentonite has a very high volume change potential due to changes in its moisture content. Aluminum silicate in bentonite is considered as the primary cause of the significant volume change potential of bentonite. This property of bentonite is considered a blessing for some applications whereas, it can be detrimental in several others. When soils to be used as fill or landfill liners are modified with bentonite, significant amount of volume change of the fill or landfill liner may be detrimental. Therefore, soils or similar materials amended with bentonite should be evaluated for their volume change potential. Some studies involving bottom ash – bentonite mixtures have addressed the issue of the effects of volume change property of bentonite on the overall swelling behavior of bottom ash-bentonite mixtures. A recent study conducted by Kumar and Vaddu (2003) has shown that strength and stiffness characteristics of bottom ash – bentonite mixtures change significantly with the curing age of the mixtures. Therefore, the aim of this study was evaluate the effect of curing on the swelling characteristics of bottom ash – bentonite mixtures.

Bottom ash-bentonite mixtures with 16 and 18 percent moisture content and 20 percent bentonite, cured for up to 28 days, were tested in this study. Test results show that swelling potential of the mixtures decreased significantly with the curing age. Testing procedure used and the results obtained in this investigation are presented in this paper.

MATERIALS USED

It is well recognized that the properties of bottom ash can vary based on the type of coal used and the type of furnace used to burn the coal. Bottom ash used in this study was obtained from a coal burning power generating plant in Springfield, Illinois which burs coal from Illinois basin. The bottom used was grey in color and its particle sizes varied from fine sand to fine gravel, with approximately 15-20 percent fine material. Before use of the bottom ash, it was air dried at a temperature of (77 ± 3 ^{o}F) and then was sieved through a U.S. Standard No. 40 Sieve. The bentonite was obtained from Central Mine Equipment Company, St. Louis, Missouri. The bentonite used was sodium bentonite with a liquid limit of 550 and plastic limit of 55.

SWELLING TEST PROCEDURE

All tests were preformed in general accordance with the procedures outlined in the American Society for Testing and Materials (ASTM D-4546-96). The soil samples were prepared at 20 percent bentonite by weight of the total volume of dry mixture. The samples were prepared at two different moisture contents, i.e., 16 and 18 percent and the dry unit weight of the samples was targeted at 100 pounds per cubic foot (pcf). In order to prepare approximately one inch high samples for swelling tests, approximately 6 inch high cylinders of the mixtures were first compacted to obtain the targeted dry unit weight. After extruding the samples from the molds, they were cut in three equal sections. One set of three samples was tested the same day they were prepared, i.e. 0 days curing. The other samples were placed and sealed in three zip lock bags, and placed in a tub of water. The purpose of placing the samples in the water was to prevent the loss of moisture from the samples and allow the samples to stay at a constant temperature. The samples were checked on at regular intervals to make sure no water leaked in and damaged the samples. The samples were then allowed to cure.

When the required curing period was reached, a set of three samples was removed from water and trimmed to fit into consolidation rings of height approximately 0.7 in. and diameter of approximately 2.5 in. Samples were trimmed carefully so that no gaps were present between the soil and the ring. The excess soil at the top and bottom of the ring was trimmed away carefully to match the sample height to the height of the consolidation ring. Once the excess material was removed the samples where weighed again to check the unit weight of the sample. The trimmed material was used to check the moisture content of the samples.

SWELLING TEST RESULTS

As discussed in the previous section, samples with 20 percent moisture, prepared at 16 and 18 percent initial moisture content were tested in this study. The samples were tested at 0, 7, and 28 days of curing. The free swell readings were taken at the same time intervals as generally taken for the consolidation test. The free swell test results are presented and discussed in this section.

Figure 1 shows the free swell response with time for samples prepared at 16 percent moisture content. The percent free swell was calculated as the ratio of the free swell at any time divided by the initial height of the sample. Each curve shown on the figure was taken from the average of two to three similar samples. Figure 1 shows that all the samples showed a rapid swelling for the first 24 hours and then swelling slowed down gradually. The tests were terminated after 72 hours because of only marginal change in free well. For the 16 percent moisture content, maximum free swell was measured to be 11.2, 8.8 and 6.8 percent at 0, 7 and 28 day, respectively. Similar results were obtained from the samples prepared at 18 percent moisture content (Figure 2). For 18 percent moisture content, maximum free swell was measured to be 8.9, 6.4 and 1.3 percent at 0, 7 and 28 days, respectively.

Figure 3 shows the variation of maximum free swell with the curing period for the samples prepared with 16 percent moisture content. As discussed in the previous section, the samples were cured by sealing the samples in ziplock bags and placing them in a tub filled with water. During the curing period moisture was not allowed to go in or out of the samples. Results presented in Figure 3 show that the swelling potential of bottom ash – bentonite mixtures decreased nonlinearly with the curing age. Between the curing period of 0 and 7 days, the swelling potential decreased significantly and the rate of decrease in swelling potential was significantly less between the curing period of 7 and 28 days. Similar results were obtained from the samples prepared with 18 percent moisture content (Figure 4).

Figure 5 shows the effect of moisture content on the swelling potential of the bottom ash-bentonite mixtures at various curing ages. Results presented in Figure 5 show that the maximum free swell decreased with the increase in moisture content. It is also clear from Figure 5 that the effect of moisture content on the maximum free swell increased significantly with the curing age. The difference between the maximum free swell of samples with 16 and 18 percent initial moisture content at 0, 7, and 28 days were measured to be 2.3, 2.4, and 5.5 percent.

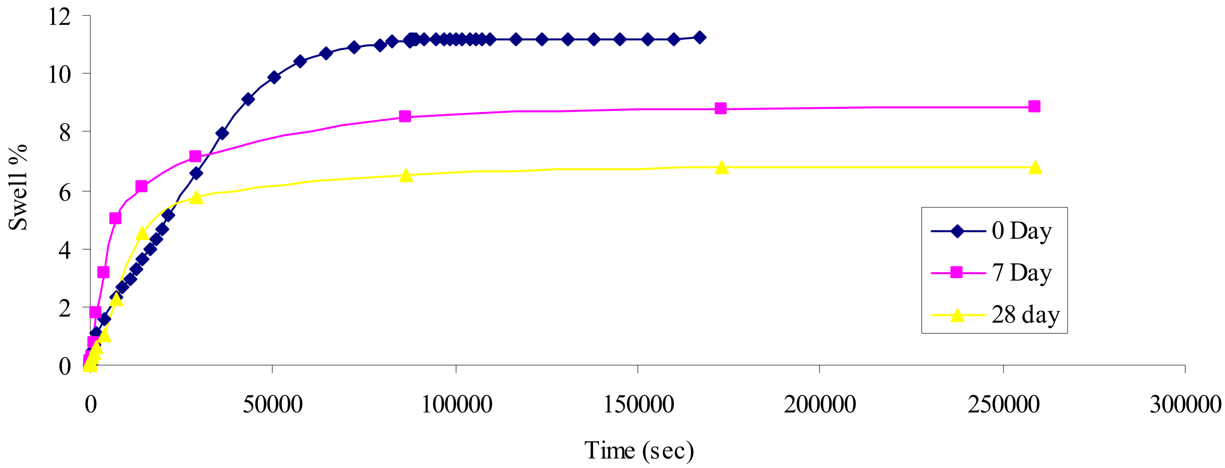

Figure 1: Percent swell versus Time for 16 % moisture content at each curing period

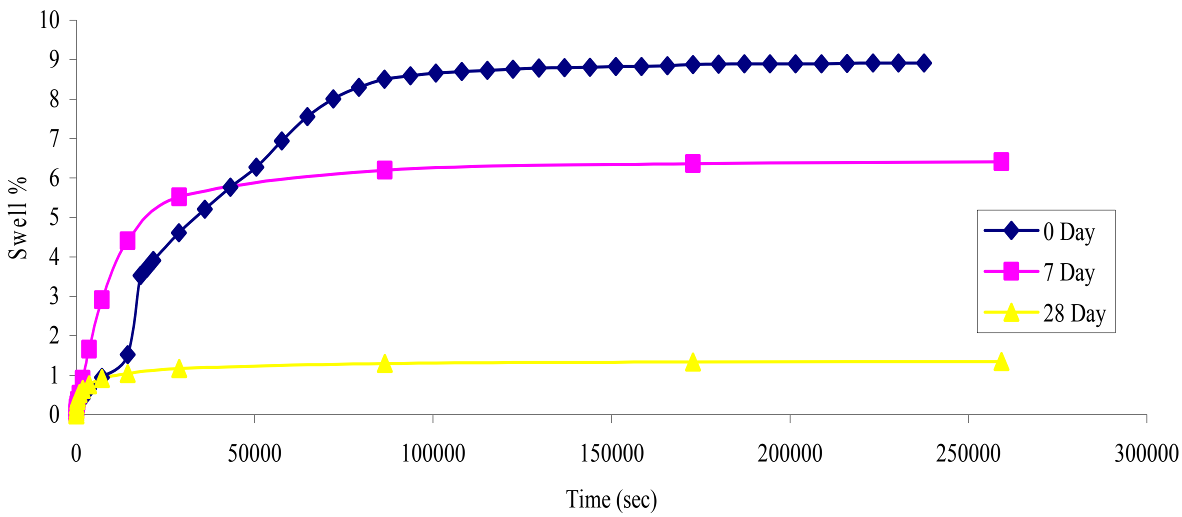

Figure 2: Percent swell versus Time for 18 % moisture content at each curing period

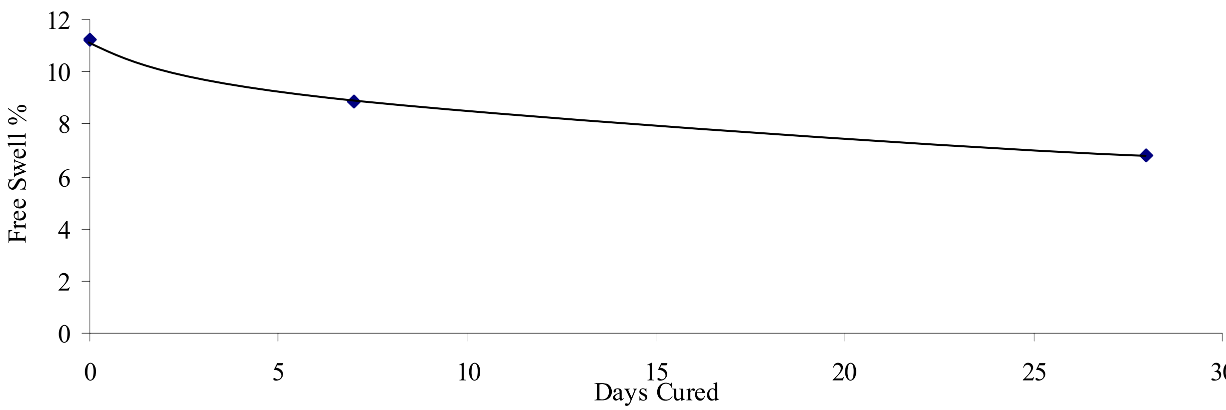

Figure 3: Maximum percent swell versus days cured for 16 % moisture content

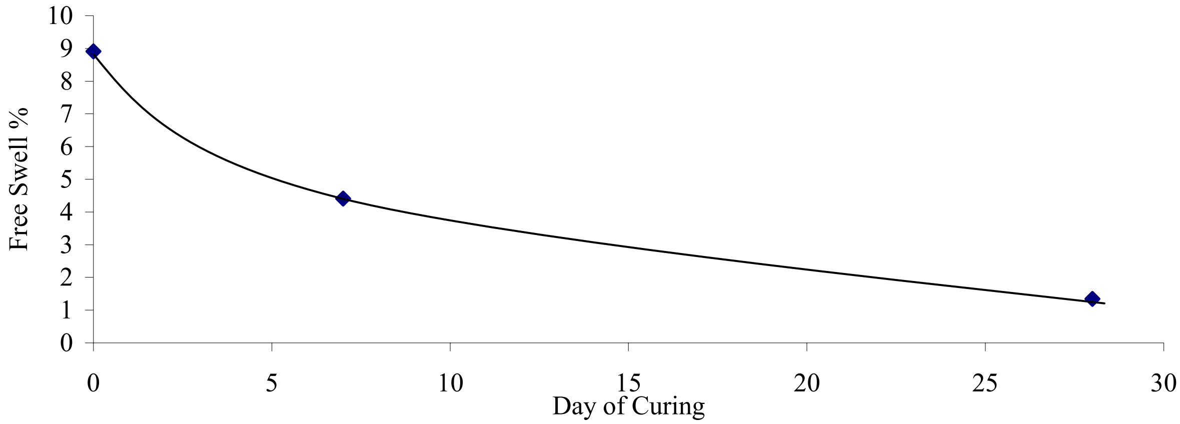

Figure 4: Maximum percent swell versus days cured for 18 % moisture content

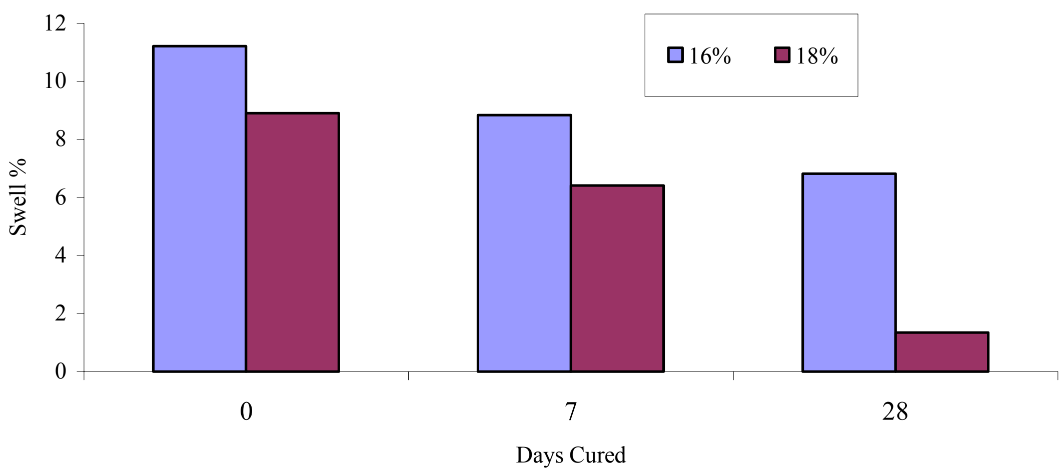

Figure 5: Maximum percent swell versus days cured for both moisture contents

CONCLUSIONS

An experimental study was conducted to investigate the effect of curing and moisture content of bottom ash – bentonite mixtures on their swelling potential. Samples containing 20 percent bentonite by dry weight of the mixture and prepared at initial moisture contents of 16 and 18 percent were tested at curing ages of 0, 7, and 28 days. Results presented show that the swelling potential of mixtures decreased significantly with the curing period. The decrease was observed to be rapid within the curing periods of 0 and 7 days compared to that within the curing periods of 7 and 28 days. Also, results presented show that the effect of moisture content on the swelling potential was significantly higher at 28 days of curing compared with the effect at 0 days of curing. Overall, the results show that curing period and the moisture content of bottom ash-bentonite mixtures have a profound affect on the swelling potential of the mixtures.

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