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Constant rate of strain consolidation of resedimented Class F fly ash

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ABSTRACT

Although the utilization of fly ash has increased over the last several decades, more than 60 percent of the fly ash produced each year in the United States continues to be disposed in ash ponds and landfills. Many disposal facilities are now or will soon be filled to their design capacity. As a result, there is an increasing interest in reclaiming existing fly ash pond areas. One possible use is as foundation for new disposal facilities, parking lots or even buildings. Before these facilities could be constructed on former fly ash ponds, the response of the fly ash to imposed loads must be determined. In the current study, constant rate of strain (CRS) consolidation tests as per ASTM D4186 were performed on medium-scale resedimented Class F fly ash samples. The compressibility behavior of the fly ash tested was found to be similar to published results for inorganic sandy silt and poorly graded sand. The value of secondary compression coefficient was found to be small.

1. Introduction

Fly ash, which is the unburned residue that exits the combustion chamber along with flue gas, is captured by air pollution control equipment (such as electrostatic precipitators or baghouses) when coal is combusted in boilers. In 2004 more than 64 million tons of fly ash were collected in the United States by these processes [1]. While fly ash utilization has increased from 8% in 1966 to 39% in 2004, most of the fly ash produced in the United States in 2004 was disposed in impoundment and landfills as an industrial waste.

Fly ash disposal is generally accomplished in one of two ways. At many facilities, fly ash is transported in the form of a slurry and deposited in ash ponds where it is allowed to settle. This method is termed as wet disposal. In contrast, the dry disposal method requires fly ash to be conditioned by adding a small amount of water and then placed in a landfill. The placement of conditioned fly ash in landfills is referred to as dry disposal. The wet disposal method has been the most common disposal practice for the past 70 years. Many disposal facilities have been or will soon be filled to their design capacity. As a result, there is an increasing interest in reclaiming existing fly ash pond. One of the attractive alternatives for utility owners is to use closed fly ash pond area as the foundation for new disposal facilities. The fly ash placed in slurry form settles and consolidates under its self-weight as well as overburden stress applied by the ash placed on top of it. The upper layer of fly ash deposited from wet disposal method has a very low density. Therefore, low bearing capacity, excessive settlement, and potential liquefaction of the fly ash deposit are of great concern to civil engineers. Many efforts have been made by researchers to study different techniques such as vacuum dewatering, electro-osmosis consolidation, vibrocompaction, stone–sand columns [2], blasting compaction [3], and lime stabilization [4] to improve the in-place density, stiffness and bearing capacity of fly ash. However, the literature review indicates very limited information being available regarding the consolidation characteristics of Class F fly ash. Consolidation characteristics concerning the rate and amount of consolidation settlement of fly ash deposit are essential for the design of any structures to be built on former ash ponds. Two of the most important properties obtained from a consolidation test are the compression index, C_c, and the coefficient of consolidation, C_V. The compression index indicates the amount of settlement that the fly ash ground can be expected to undergo while the coefficient of consolidation determines how fast the settlement will take place after loading is applied. Some research has been done to investigate the consolidation characteristics of compacted (dry disposal method) fly ash [5,6]. The consolidation characteristics of sedimented fly ash slurry has rarely been reported in the past.

Consolidation behavior of a soil is typically determined using conventional oedometer tests, which have been used by geotechnical engineers for more than six decades. Specified incremental

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loads are usually applied to the sample with a loading duration of one day per increment, giving a total testing period of one to two weeks. The sample is usually recompacted to the desired density and moisture content directly into the consolidation ring or it may be trimmed from representative field sample. In part because of the high stress gradients imposed in the conventional tests, the interpretation of data can be time consuming and requires some judgment. Constant rate of strain (CRS) consolidation test (ASTM D4186 [8]) is an efficient and relatively rapid alternative method to determine consolidation properties. In the CRS consolidation test, the sample is loaded continuously rather than incrementally and at a rate designed to produce the desired constant rate of strain. Compared with oedometer tests, the saturation of the sample can be easily achieved and maintained. During the test, the applied load, corresponding strain, and the pore water pressure are monitored continuously. CRS tests, therefore, can produce a continuous compression curve with greater objectivity than oedometer tests.

In this study, constant rate of strain (CRS) consolidation tests as per ASTM D4186 were performed on medium-scale resedimented Class F fly ash samples that simulated wet disposal in an ash impoundment.

2. Basic properties of the fly ash

The fly ash tested in this study was produced by the Cardinal power plant of American Electric Power (AEP) in Brilliant, Ohio. The Cardinal fly ash was classified as a Class F ash as per ASTM C618. The basic physical properties, such as particle size analysis and specific gravity, were evaluated using representative samples from the ash pond at the power plant.

Compared to most soils, fly ash has a lower specific gravity that typically ranges from 2.1 to 2.5 [7]. In this study, the specific gravity of Cardinal fly ash was found to range from 2.1 to 2.4 with an average value of 2.2.

Typically, fly ash is a relatively fine predominantly silt sized uniform material [7]. Fig. 1 shows the grain size distribution curves for the fly ash used in this study. Numerical analysis results of the gradations are presented in Table 1, including the median particle size (D_{50}), the effective particle size (D_{10}), and the coefficient of uniformity ($C_u = D_{60}/D_{10}$). The median particle size describes the average particle size for the sample. Effective particle size reflects the maximum diameter of the smallest 10 percent particle. The coefficient of uniformity is used to relate the size range of the particles. The ponded fly ash consisted predominantly of silt size particles with some clay- and sand-size fractions. The fly ash was poorly graded with a coefficient of uniformity ranging from 3.3 to 6.0.

Table 1
Gradation test results.

Sample ID	Particle size analysis		
	D_{50} (mm)	D_{10} (mm)	C_u
Fly ash sample 1	0.014	0.0045	3.3
Fly ash sample 2	0.018	0.0040	6.0
Fly ash sample 3	0.018	0.0040	5.0

3. Sample preparation and test procedures

All the resedimented samples were prepared as a slurry to simulate the wet disposal method employed at the ash ponds. Wet fly ash taken from the pond was combined with distilled water and mixed thoroughly in three flasks. The mixture was saturated by applying a vacuum until no air was drawn out of the slurry. After saturation, the slurry was carefully poured into a consolidometer modified from a 14 cm (5.5 in) diameter triaxial chamber and allowed to sediment for a minimum of two hours.

After the sample settled under its self-weight, a custom-made cap was put on top of the sample and the triaxial chamber was assembled (Fig. 2). The cap consisted of two parts (see details in Fig. 3). The top part had a Teflon ring which provided a close fit between the top cap and the chamber to prevent leakage of fly ash

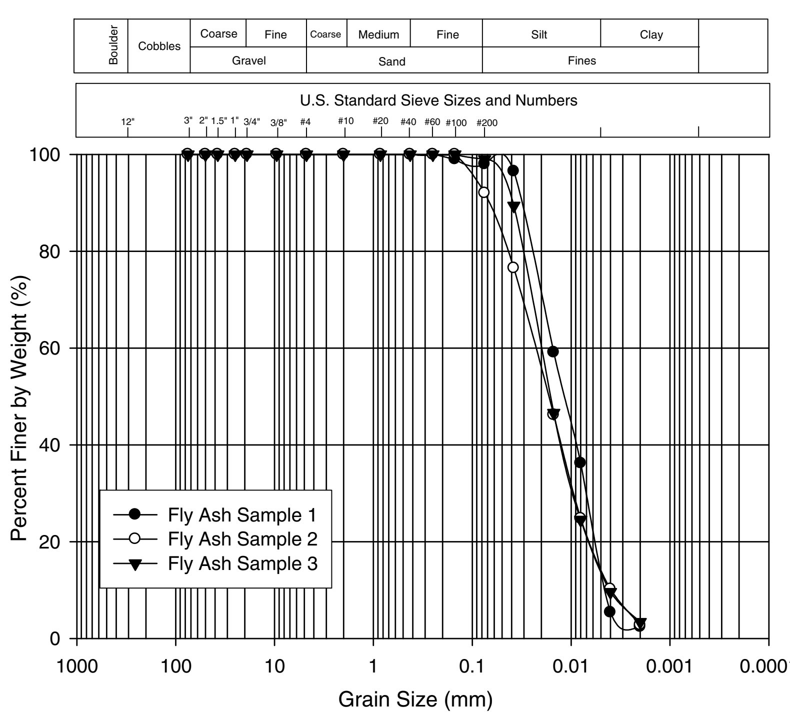

Fig. 1. Grain size distribution of fly ash.