Geotechnical and Geoenviornmental Characterization of TTPS Pond Ash and Its Utilization

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ABSTRACT: The present paper emphasizes on geotechnical and geoenviornmental characterization of pond ash sample collected from TTPS (Talcher Thermal Power Station), Talcher, Odisha. Laboratory tests have been performed to investigate both geotechnical and geoenvironmental properties of the pond ash sample. The geotechnical properties such as specific gravity, physical properties, consistency, light compaction, direct shear, permeability, consolidation and collapsibility test have been performed. Similarly, the geoenviornmental properties such as potential of hydrogen (pH), lime reactivity test, soluble sulphate content, leachability and heavy metals, X-Ray diffraction and scanning electron microscope (SEM) have been carried out. Based on the test results, its utilization as an alternate backfill material has been suggested. The effects of pond ash on nearby environment are also discussed.

Keywords: *Pond ash, Collapsibility, Sulphate content, Lime reactivity, Leachability.*

1. Introduction

In India, a major portion of power is generated through coal based thermal power plant. Coal ash is generated in huge amounts as a byproduct from these thermal power plants. The coal ash is differentiated into fly ash, bottom ash and pond ash. As a waste material the coal ash including pond ash can affect both nearby soil and environment. So there is requirement for proper disposal of these byproducts. At the same time these can be used as a replacement to certain types of construction material. Hence, the geotechnical and the geoenvironmental properties need to be studied properly.

Pandian (2004) reported that Pond ash generally contains silt size fractions and some sand size fractions, having silica content in the range of 37-75%, alumina content in the range of 11-53%. Specific gravity significantly affects the dry density of pond ash. Also, the MDD increases with the increase in compaction energy as reported by Bera et al. (2007). The specific gravity and compacted maximum dry density of pond ash have a significantly lower value than those of sand as reported by Jakka et al. (2010). Crushing strength can be a useful parameter in evaluating the shear characteristic of the granulated coal ash according to Yoshimoto et al. (2012). The components of these waste materials may be harmful for nearby soil and environment. Toxic trace metals present in coal ash may leach after contact with water as reported by Baba and Turkman (2001). pH has a great effect on leaching of metals like Boron, Manganese, Molybdenum, Selenium. Increase in pH results in increase of these metals according to Cetin and Aydilek (2013). Sometimes these waste materials can be used as replacement for various materials. According to Mudd et al. (2007), sometimes the leached ash can be preferably used as cover material as it possesses high storage capacity, low permeability and is mildly alkaline.

In the present study, the geotechnical and geoenvironmental characteristics of the pond ash collected from TTPS, Odisha is studied by laboratory tests. The geotechnical characterization aims at investigating the suitability of the pond ash as a geotechnical construction material and the geoenvironmental characterization aims at finalizing whether the pond ash is fit for the surrounding environment or not.

2. Materials and Methodology

The pond ash is collected from Talcher Thermal Power Station (TTPS), Odisha. To determine geotechnical properties of the samples various tests have been performed on these samples, according to the provisions mentioned in Standardized Codes.

The collapse index of the pond ash is measured according to ASTM D 5333-03. The specimen is compacted at its MDD and OMC corresponding to light compaction. The specimen is placed in a consolidometer. The load was applied to the specimen at the rate of 0.1, 0.25, 0.5, 1, 2, 4, 8, 15 and 30 min, and 1, 2, 4, 8 and 24 hours respectively. Potential collapse in the soil specimen is induced by applying a predetermined vertical stress (i.e. 200 kPa) to the specimen and inundating the specimen with fluid. The relative magnitude of soil collapse determined at 200 kPa is called as collapse index (I_e) is calculated using Eq. (1).

$$I_e = \left[\frac{d_f - d_i}{h_o} - \frac{d_i - d_o}{h_o}\right] 100 \qquad (1)$$

Where;
d_o=dial reading at seating stress, mm,
h_o=initial specimen height, mm,
d_f=dial reading at the appropriate stress level after wetting, mm,
d_i=dial reading at the appropriate stress level before wetting, mm,
$(d_f - d_o)/h_o$=strain at the appropriate stress level after wetting, and
$(d_i - d_o)/h_o$=strain at the appropriate stress level before wetting.

Similarly, the geoenviornmental properties such as pH (IS 2720: Part 26), Lime reactivity (IS 1727: 1967), Soluble sulphate content (ASTM C1580-09), Batch Leaching test (ASTM- D 4793-09), XRD and SEM analysis of pond ash have been carried out in the laboratory.

3. Results and Discussions

Both the geotechnical and the geoenviornmental properties of the ash samples, which were obtained from the laboratory tests, are discussed below.

3.1 Geotechnical characterization

The specific gravity of the pond ash is found to be 2.16. Due to the lower value of specific gravity it can be used as backfill material for retaining structures. The geotechnical properties of the pond ash are given in Table 1.

Table-1 Geotechnical properties of pond ash

Geotechnical Properties	Parameter(s)	Pond Ash
Physical Properties	D_{10} (mm)	0.004
	D_{30} (mm)	0.012
	D_{60} (mm)	0.035
	Coefficient of curvature, C_c	1.03
	Coefficient of uniformity, C_u	8.75
Liquid limit, *LL* (%)		38
Plastic Limit, *PL* (%)		N_P
Plasticity Index, *PI* (%)		N_P
Compaction Characteristics	Maximum dry density, MDD (kN/m^3)	11.3
	Optimum Moisture content, OMC (%)	30
Shear Strength	Cohesion, *c* (kPa)	4.0
	Angle of Internal friction, ϕ^o	21.3
Permeability	Coefficient of Permeability, *k* (cm/sec)	7.9 x10^{-5}
Consolidation	Coefficient of compression, C_c	0.03
	Coefficient of consolidation, C_v (cm^2/sec)	0.77x10^{-3}
Collapsibility	Collapse Index, I_e (%)	0.6
Differential free swell (DFS) index (%)		-34

The particle size distribution curve of TTPS pond ash is given in Fig.1. The compaction and shear strength characteristics are given in Figs. 2 and 3 respectively. The variation of void ratio with respect to applied pressure is presented in Fig. 4. From Fig. 4, it can be observed that the material is low compressible. The compression curve obtained from the collapsibility test is given in Fig. 5, from which it is observed that the I_e is found to be 0.6 %. As per ASTM D5333-03, the pond ash is slightly collapsible (0.1% < I_e < 2%) in nature.

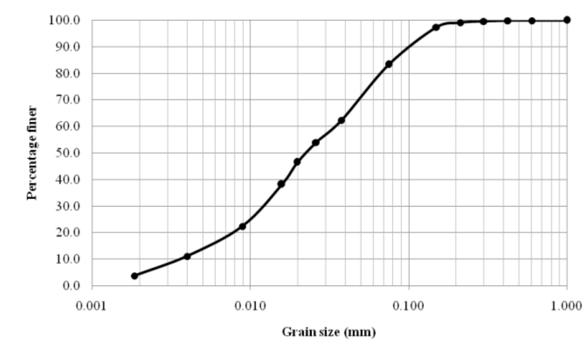

Fig. 1 Grain size distribution curve of pond ash

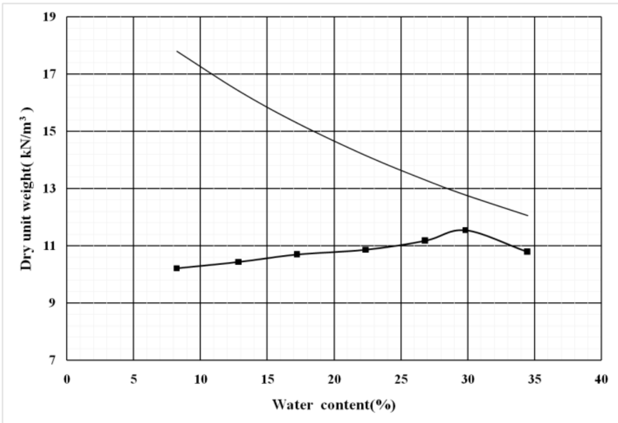

Fig. 2 Light compaction curve of pond ash

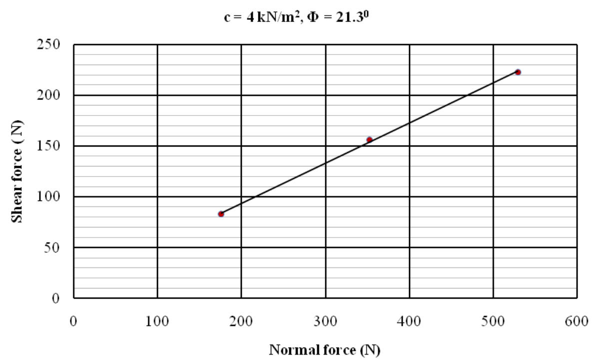

Fig. 3 Direct shear test of pond ash

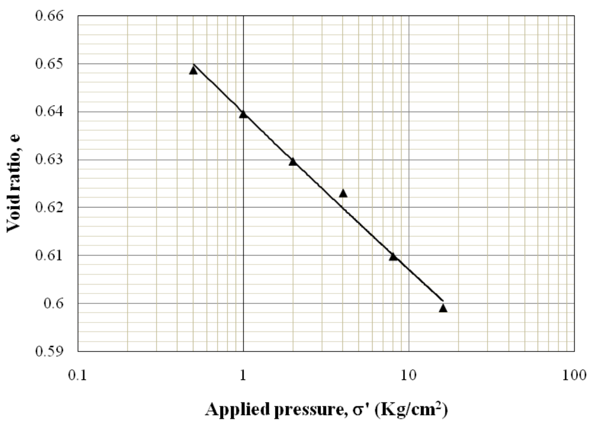

Fig. 4 e-log P relationship curve for TTPS Pond ash

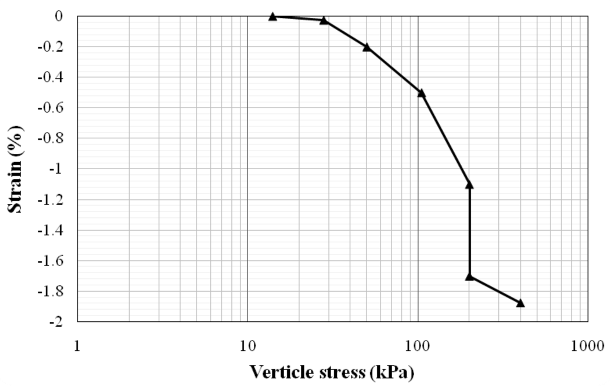

Fig. 5 Compression curve for Collapse index of TTPS Pond ash

3.2 Geoenvironmental characterization

The pH of the pond ash sample is found to be 6.94, indicating that the sample is almost neutral. The compressive strength obtained from the lime reactivity test and the soluble sulphate content of pond ash is given in Table 2. It is found that the pond ash can be used as a pozzolanic material as it satisfies the criteria as mentioned in "IS 3182: Pulverized Flue Ashes Specification" (compressive strength > 4.5 MPa). It is also observed that the TTPS pond ash is free from sulphate content.

The results from batch leaching test for different liquid/solid (L/S) ratio are presented in Table 3. In general, TTPS pond ash contains higher amount of reactive Magnesium (Mg) in comparison to other heavy metals such as Iron (Fe), Zinc (Zn) and Nickel (Ni). The reactive Ni content is negligible in pond ash. For pond ash keeping the solvent quantity fixed when the mass of material was varied, the amount of leached Fe, Mg and Zn is found to be decreased. The amount of Zn, and Mg present in the leachate of TTPS pond ash are within the permissible limit as per IS 10500 (2012). Fe content in the leachate of pond ash (L/S ratio of 50 and 100) is within permissible limit. However, for pond ash (L/S =10), the Fe content is exceeding the permissible limit as per IS 10500 (2012), as mentioned in Table 3.

Table-2 Compressive strength and sulphate content in pond ash

Geo-environmetal Properties	**Parameter(s)**	**Pond ash**
Compressive Strength	Comp. strength of Sample 1 (MPa)	4.78
	Comp. strength of Sample 2 (MPa)	5.31
	Comp. strength of Sample 3 (MPa)	5.66
	Avg. compressive strength (MPa)	5.25
	Std. deviation	0.44
Soluble Sulphate Content	SO_4 (%)	0
	SO_4 (mg/Kg)	0
	Permissible limit in soil (%) [by American Concrete Institute (ACI)]	0.1 - 0.2

Table-3 Leaching properties of pond ash

Sample	**Heavy Metal (mg/lit)**	**L/S=10**	**L/S=50**	**L/S=100**	**Permissible limit as per IS 10500 : 2012**
Pond Ash	Fe	0.818	0.248	0.106	0.3
	Zn	0.09	0.071	0.045	15
	Mg	1.561	0.57	0.433	100
	Ni	0	0	0	0.02

The X-ray diffraction test on the pond ash sample reveals that, the major minerals are quartz, mulite, dolomite, and magnetite as observed from Fig. 6. The morphological studies, which are carried out using Scanning Electron Microscope (SEM), indicate that the pond ash contains spherical particle with agglomerates of irregular shape as shown in Fig. 7.

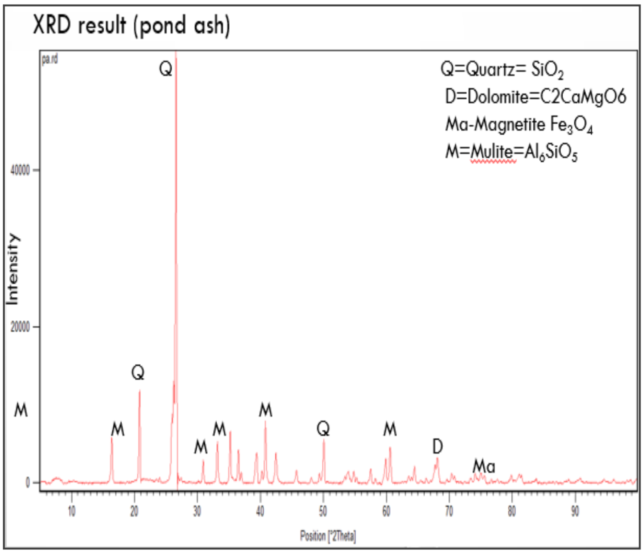

Fig. 6 XRD image of pond ash sample

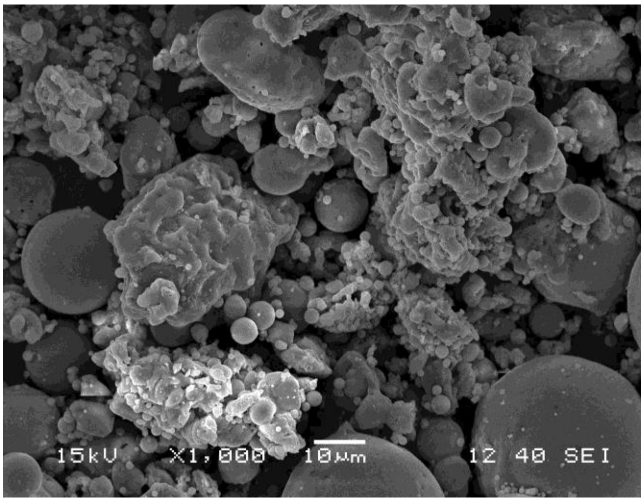

Fig. 7 SEM image of pond ash at 1000X

4. Conclusions

Based on the geotechnical and geoenvironmental tests conducted in the laboratory on collected pond ash sample from TTPS, Odisha, the following conclusions may be drawn:

- The compressive strength of pond ash is high along with lime and sand which enhance pozzolanic properties.
- The TTPS Pond ash is low compressible in nature and slightly collapsible type of material.
- TTPS pond ash has normal pH range which has no effect on ground water. The pond ash collected from TTPS don't have soluble sulphate content otherwise would have adverse effects on the soundness of the structure.
- The reactive Ni content is negligible for pond ash.
- The amount of Zn and Mg present in the leachate of TTPS pond ash are within the permissible limit as per IS 10500 (2012) and hence no effect on the drinking water.
- Except for pond ash (L/S =10), the Fe content in the leachate of pond ash for all L/S ratios is within the permissible limit as per IS 10500 (2012*).*
- It may be used as an alternate backfill material.

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