# Geotechnical Characteristics of Thermal Powertech Fly Ash from Krishnapatnam, Nellore

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**Abstract.** Thermal power plants continue to produce large quantities of fly ash, which becomes the source of pollution of ground water, besides consuming large areas of valuable land for disposal. Geotechnical engineering provides vast scope for utilization of fly ash as a substitute to soil in embankments and subgrades. Knowledge of geotechnical characteristics of fly ash helps to promote bulk utilization of fly ash. This paper investigates the physical, morphological, index and engineering characteristics of fly ash (hereafter referred as TPFA) from Thermal Powertech Corporation India Limited, Krishnapatnam, Andhra Pradesh. The OMC and MDD of TPFA have been determined under I.S.Heavy compaction. The shear parameters, CBR and permeability of TPFA have been determined at OMC. Lime (0-10%) and polyester fibers (0-6%) are used as a stabilizer in different proportions to study possible improvement in engineering characteristics of TPFA and the results are presented in this paper. The results are analyzed and suitability of TPFA for use in embankments and subgrade, as a substitute to soil, has been assessed. The results of the study are expected to enhance the awareness among the engineers and help to promote potential use of TPFA in embankments and subgrades, saving soil thus leading to sustainable development.

**Keywords:** Fly ash, Geotechnical characteristics, Embankment, Nellore.

## 1 Introduction

Thermal power plants continue to produce large quantities of fly ash, which becomes the source of pollution of ground water, besides consuming large areas of valuable land for its disposal. Geotechnical engineering provides vast scope for using fly ash as a substitute to soil in embankments, subgrades for highways as well as backfill material. Fly ash utilization requires the knowledge of geotechnical characteristics of fly ash and this enhances the awareness among the engineers and promotes its bulk utilization. The geotechnical characteristics of fly ash vary from one thermal plant to the other and also from time to time within a plant. This necessitates the study of geotechnical characteristics of fly ash from thermal power plants.

This paper investigates the physical and engineering characteristics of low calcium fly ash from Thermal Powertech Corporation India Ltd., Krishnapatnam, located about 24 km from Nellore in Andhra Pradesh. The plant, established in 2015 with total power generation capacity of 1320MW (2×660 MW), is now known as Sembcorp Energy India Limited (SEIL), Phase-I, as it was taken over by SEIL, Singapore. The fly ash from Thermal Powertech Limited, hereafter referred as TPFA, is collected by using Electrostatic Precipitators. The utilisation of TPFA is around 50%.

## 2 Literature Review

Sarat Kumar Das and Yudhbir, 2005 [1] reported the engineering properties of Parichha (Jhansi) and Panki (Kanpur) fly ash from Neyveli Lignite Corporation, to evaluate their suitability as embankment materials and reclamation fills. Sridharan et al. 2002 [2], Porbaha et al. 2000 [3], etc. have characterized low calcium fly ashes for utilization as embankment and fill material.

Sridharan, 2012 [4] reported that low to very low specific gravity of coal ashes (i.e. 1.47 – 2.78) makes them suitable for the use as construction fill materials and as embankment materials. CBR of fly ash from Raichur power plant is found to be 6.9% in unsoaked condition and 3.5% in soaked condition. The corresponding values for fly ash from Vijayawada thermal power plant are found to be 20.6% and 0.2%.

Dharavath et al. 2010 [5] reported the results of stabilization of fly ash with lime and gypsum. Increase of lime content from 5 to 12% increased the unconfined compression strength of fly ash from 113 kPa to 162 kPa. Shenbaga and Gayathri, 2003 [6] used polyester fibers of 1% with fly ash and showed that fiber inclusions increased the strength of fly ash specimens.

Narasinga Rao and Sai Revathi, 2019 [7] presented the geotechnical characteristics of class F fly ash from NTPC, Visakhapatnam for use as structural fill material. Narasinga Rao and Suryanarayana, 2020 [8] studied the compaction and CBR characteristics of Hinduja fly ash from Visakhapatnam with and without lime and polyester fibres as admixtures.

## 3 Materials and Methods

Samples of TPFA have been collected from the Ash silo of the plant, in 50 kg bags and transported to the geotechnical engineering laboratory, ANITS. Chemical analysis data from the plant indicates that CaO content is negligible and therefore TPFA is Class F fly ash.

The fly ash samples have been subjected to IS Heavy compaction (Modified Proctor) tests, apart from physical properties. Direct shear test, CBR Test and Permeability test were also conducted on fly ash samples compacted at OMC. Soaked CBR tests did not yield any measurable resistance to penetration. Only unsoaked CBR tests were conducted.

The specific surface of TPFA is determined using Blaine's air permeability apparatus. XRD, SEM and FT-IR analysis is carried out at Advanced Analytical Laboratory, Andhra University, Visakhapatnam.

To study the possible improvement in the properties of TPFA, polyester fibers and lime have been used as admixture in this study. The polyester fibres are Recron 3s brand of Reliance Industries with 6 mm cut length and 20μ-40μ Effective diameter. Commercially available HiTech-Gold lime is used in the study and obtained from Vijaya Lime Products.

The fly ash is the mixed with the admixture in different proportions in dry powder form, mixed thoroughly and the OMC, MDD and CBR are determined. These tests are conducted immediately after adding required water (0 days curing). To study the effect of curing, the dry TPFA and the admixture are added with required water, covered the containers with wet cloth and cured for 2 days. Heavy compaction and CBR tests are conducted after 2 days curing. All the tests were done for TPFA without adding admixture also for control data.

All the tests have been done as per relevant Indian Standards (I.S.2720). Each test is conducted twice and the average of the values obtained from the two trials has been adopted. The % variation of the individual values from the average was observed to be marginal.

## 4 Results and Discussion

### 4.1 Physical and Index Properties of TPFA

Fig.1 shows the grain size distribution curve of TPFA. The fly ash has 83.6% fines with predominantly silt size particles (79.7%) and negligible clay size particles (3.9%), the remaining being sand (16.4%). The fly ash is found to be non-plastic and hence is basically sandy silt. As per I.S. Soil classification system, TPFA may be classified as ML (Low plastic Silt).

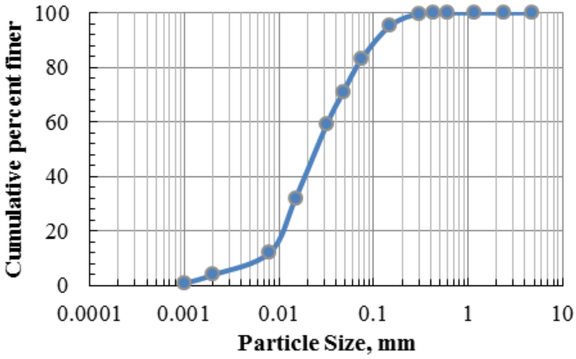


**Fig. 1.** Grain size distribution curve of TPFA.

The specific gravity of TPFA particles is found to be 2.20 and its specific surface is 3309.9 $cm^2/g$. The XRD pattern of TPFA (Fig.2) indicates presence of Quartz with very strong peak at 2θ of 26.9° and other peaks at 21.13° and 39.50°, while Mullite is indicated by the strong peaks at 41.08° and 60.12° and other peaks at 16.77°, 33.52° etc. The peak at 31.23° is likely to indicate gypsum/anhydrite.

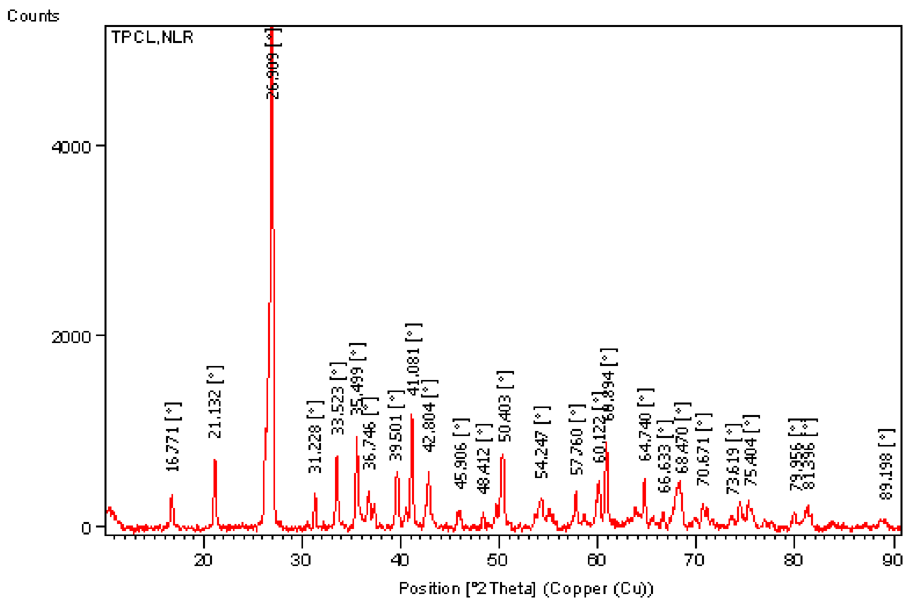


**Fig. 2.** XRD Pattern of TPFA

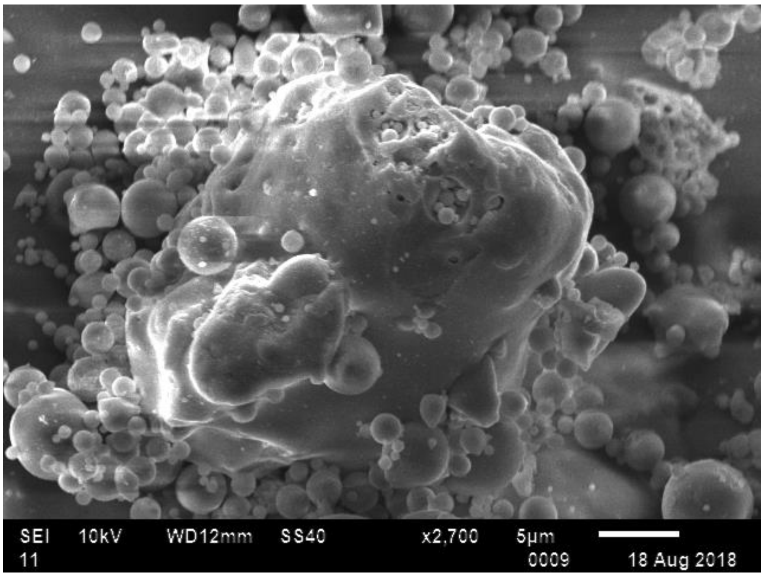


**Fig. 3.** SEM Micrograph of TPFA

The SEM Micrographs (Fig.3) indicate that TPFA particles are spherical in shape showing mostly silt sized particles and a few clay size particles. The FT-IR spectrum of TPFA (Fig.4) shows the main absorption band of the valence oscillations of the groups Si-O-Si in Quartz at 1089 cm$^{-1}$. The band at 2362 cm$^{-1}$ may be due to carbon impurities.

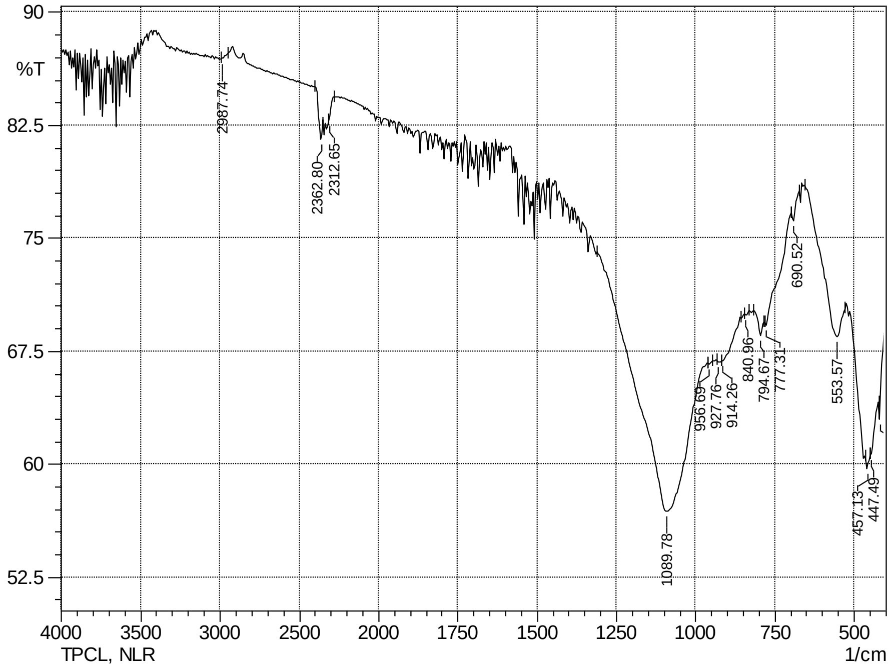


**Fig. 4.** FT-IR Spectrum of TPFA

## 4.2 Engineering Characteristics of TPFA with and without admixtures

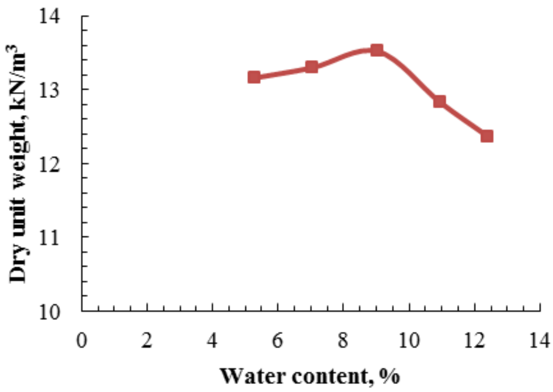


**Fig. 5.** Compaction curve of TPFA

Fig.5 shows the water content-dry unit weight relation for the TPFA under I.S. Heavy compaction. The MDD obtained for TPFA is 13.5 kN/m$^3$ at OMC of 8.7 %. It is observed that the dry unit weight of TPFA is not significantly sensitive to water content. This is also reported in earlier studies by Sridharan, 2012 [4] and Ambarish and Subbarao, 2007 [9]. This nature of fly ash is beneficial for its field applications, as minor variation of field moisture content may not alter the field dry unit weight of the compacted layer appreciably. The shear parameters of TPFA obtained from direct shear test are c=19.3 kN/m$^2$ and 21.3°. The CBR in unsoaked condition at OMC is obtained as 11.4% and the permeability is found to be 6.16×10$^{-5}$ cm/s.

### 4.3 Effect of Lime and Polyester fibers on OMC and MDD of TPFA

Table 1 presents the OMC and MDD of TPFA when mixed with lime/polyester fibers in different percentage. Addition of lime, in general decreases the OMC of TPFA, the decrease being more pronounced at 5% lime content. MDD of TPFA is not apparently affected by addition of lime without curing. However, with 2-days curing, the MDD increases marginally at 5% and 8% lime, while it decreases at 10% lime. Earlier study by Ambarish and Subbarao, 2007 [9] also shows no significant increase in MDD of Class F fly ash from Kolaghat Thermal Power Station, India on addition of lime up to 40%.

Addition of polyester fibers appears to increase the OMC and decrease the MDD of TPFA, the effect increasing with increase of fiber content. Curing does not appear to have any significant influence on OMC and MDD of TPFA with Polyester fibers as admixture. The specific gravity of polyester fibers (~1.34) is significantly less than that of the TPFA (2.2), which may have caused the decrease in MDD. Further, the addition of fibers may have affected the gradation of the fly ash causing increase in OMC and decrease in MDD of TPFA.

**Table 1.** Compaction Characteristics of TPFA with and without Admixtures

| Lime % | 0 days Curing | | 2 days Curing | | Polyester Fibers % | 0 days Curing | | 2 days Curing | |
|---|---|---|---|---|---|---|---|---|---|
| | OMC | MDD | OMC | MDD | | OMC | MDD | OMC | MDD |
| 0 | 8.7 | 13.5 | 8.7 | 13.5 | 0 | 8.7 | 13.5 | 8.7 | 13.5 |
| 5 | 7.9 | 13.6 | 6.6 | 14.1 | 2 | 10.3 | 13.0 | 10.4 | 12.9 |
| 8 | 8.2 | 13.6 | 6.6 | 14.0 | 4 | 12.1 | 12.5 | 11.9 | 12.3 |
| 10 | 8.4 | 13.6 | 7.7 | 12.0 | 6 | 11.9 | 12.2 | 11.7 | 12.1 |

OMC in %; MDD in kN/m$^3$

### 4.4 Effect of Lime and Polyester fibers on Friction angle of TPFA

McLaren and DiGioia, 1987 [10] says that the strength property of major interest for fly ash is $\phi$, the friction angle. Table 2 presents the Friction angle of TPFA when mixed with lime/polyester fibers in different percentage. Addition of lime, in general appears to increase the friction angle of TPFA, and the curing has significant positive effect. The friction angle of 0-10% lime treated TPFA is in the range of 21.3°-25.5° without curing and 21.3°-26.1° with 2 days curing, respectively.

Addition of 0-6% polyester fibers appears to increase the friction angle of TPFA from 21.3°-25.2° without curing and 21.3°-26.6° with 2days curing, presumably due to the reinforcing effect of the fibers due to skin friction between fiber and fly ash. Curing does not appear to have a systemic influence on the fiber reinforced TPFA.

**Table 2.** Friction Angle (ϕ) of TPFA with and without Admixtures

| Lime % | Curing Period | | Polyester Fibers % | Curing Period | |
|---|---|---|---|---|---|
| | 0-d | 2-d | | 0-d | 2-d |
| 0 | 21.3 | 21.3 | 0 | 21.3 | 21.3 |
| 5 | 21.5 | 25.1 | 2 | 22.1 | 21.6 |
| 8 | 22.2 | 25.8 | 4 | 24.5 | 26.6 |
| 10 | 25.5 | 26.1 | 6 | 25.2 | 24.0 |

ϕ in degrees

### 4.5 Effect of Lime and Polyester fibers on CBR of TPFA

The unsoaked CBR of the TPFA improved significantly from 11.4% to 48.2% when the lime content is increased from 0 to 5%. Further increase in lime content caused an increase in CBR, which is less than that with 5% lime. Curing has a significant influence on CBR of TPFA fly ash with lime as admixture. Addition of lime to fly ash increases the availability of lime for pozzolanic reaction leading to increase in CBR, as also reported earlier [9].

Polyester fibers of 2% improved CBR of TPFA fly ash from 11.4% to 35.2% with 0 days curing, presumably due to skin friction between fiber and fly ash. Further increase in polyester fiber content caused an increase in CBR, which is less than that with 2% polyester fibers. Curing has no significant effect for improvement of CBR of TPFA fly ash with polyester fibers.

## 5 Conclusions

The present study investigated the physical and engineering characteristics of TPFA with and without lime and polyester fibers as admixtures and the following conclusions have been drawn, based on the results obtained from the study.

1. TPFA fly ash is non-plastic sandy silt and classified as ML. The dry unit weight of TPFA is not significantly sensitive to water content. Also TPFA has no measurable CBR value in soaked condition.
2. The unsoaked CBR of the TPFA improved significantly from 11.4% to 48.2% when the lime content is increased from 0 to 5%. Curing has a significant influence on CBR of TPFA fly ash with lime as admixture.

3. Polyester fibers of 2% improved CBR of TPFA fly ash from 11.4% to 35.2%. Curing has no significant effect for improvement of CBR of TPFA fly ash with polyester fibers as admixture.
4. The TPFA is suitable as a substitute to soil in embankments and subgrade and 5% lime or 2% polyester fibers have significantly improved its unsoaked CBR. Soil cover of suitable thickness will be necessary due to poor CBR of TPFA in soaked condition.

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