Appraisal of Suitability of Fly ash as Fill/Backfill Material in Civil Engineering Constructions

D. Jyothi Swarup[1] R. Sai Chandu[2] and C.N.V. Satyanarayana Reddy[3]

[1]Research Scholar, Department of Civil Engineering, Andhra University College of Engineering, Visakhapatnam, Andhra Pradesh -530040
[2]Research Scholar, Department of Civil Engineering, Andhra University College of Engineering, Visakhapatnam, Andhra Pradesh -530040
[3]Professor, Department of Civil Engineering, Andhra University College of Engineering, Visakhapatnam, Andhra Pradesh -530040

jyothiswarupdeevi@gmail.com
ronankisaichandu@gmail.com
prof.cnvsreddy@andhrauniversity.edu.in

Abstract. More than 200 million tons of fly ash is generated per annum from the thermal power plants (Central Electricity Authority 2020) in India. Thorough information on geotechnical characteristics of fly ash helps in promoting bulk utilization of fly ash in various civil engineering constructions. Many researchers recommendedthe suitability of fly ash as a construction material based on its strength characteristics (ϕ and CBR value). However, Compressibility characteristics of fly ash are required for predicting the settlements to ensure the serviceability of structures founded on it. Hence,the present study is intended to evaluate compressibility characteristics (C_v& C_c) of fly ash by performing one dimensional consolidation tests. The results indicated that fly ash has compression index (Cc) 0.165 of in saturated state, which is in the range of value of compression index of commonly used fill material of embankments, i.e. low compressible clay (Cc= 0.14-0.23).

Keywords: Fly Ash, Fill, Back Fill, Compressibility, Strength, CBR, Embankment.

1 Introduction

Reinforced soil is being widely used in the construction of various civil engineering structures such as reinforced earth retaining walls, reinforced embankments, preparation of reinforced soil bed, reinforced flexible pavements etc. Granular soils such as river sand and moorum are commonly used as fill materials in construction of reinforced earth retaining walls, embankments etc. Due to the increase in cost of conventional fill materials, alternative cost-effective fill materials are to be explored.Several industrial wastes such as coal ashes, crusher dust, granulated blast furnace slag etc. have already found applications in civil engineering constructions due to their better gradation and strength characteristics [5,12,15,16].
Among various industrial wastes, Fly ash can be successfully used to stabilize weak soils or as an alternative to conventional fill material in the construction of embankments in weak subgrades due to its higher angle of shearing resistance and lower values of density [7,9,10,11,14]. The improvement in the strength of a weak soil

can be better pronounced when fly ash is used in combination with lime and GGBS [2,3,4,17]. The inclusion of various fibers further increases the strength and ductility of fly ash [1,13].

However, the authenticity of its performance under the acting loads in events of saturation cannot be substantiated as no considerable studies complimenting the compressibility characteristics of these materials were reported in the literature. Since the compressibility of fly ash is appreciably influenced by the curing period [16], detailed compressive studies are essential to advocate their use and better performance as fill/backfill materials in embankments, reinforced soil structures etc. under the loads.

On realizing the gradation and strength characteristics of fly ash through extensive laboratory investigation carried out by numerous researchers, India has started using fly ash in the construction of highway embankments. In this scenario, Compressibility of fly ash is also required to be evaluated along with strength characteristics. Hence, the present study is intended to evaluate the compressibility characteristics i.e., coefficient of consolidation and compression index of fly ash to assess its suitability further as a fill material.

2 Material Properties

Fly ash required for the study is procured from NarllaTatarao Thermal Power Station (NTTPS), Vijayawada, Krishna District. Engineering properties of fly ash evaluated by conducting laboratory tests are presented in Table 1. IS heavy compaction test (IS 2720 part VII) is conducted to determine compaction characteristics of Fly Ash. From Table 1, it is observed that fly ash contained predominantly silt sized particles. Based on gradation and plasticity characteristics fly ash is classified with the symbol MLN (Non-Plastic low compressible Inorganic Silt) as per theclassification procedure suggested by Sridharan (2006).

Table 1. Engineering Properties of Fly Ash.

Property	Value
Specific Gravity	2.08
Grain Size Analysis	
i. Gravel (%)	0
ii. Sand (%)	25
iii. Silt (%)	75
iv. D_{10} (mm)	0.0033
iv. D_{30} (mm)	0.0082
v. D_{60} (mm)	0.02
vi. C_u	5.71
viii. C_c	0.96
Plasticity Characteristics	
a) Liquid Limit	NP
b) Plastic Limit	NP
Compaction Characteristics	
a) Optimum Moisture Content (%)	23

b) Maximum Dry Density (g/cc)	1.3
Shear Parameters	
i). OMC-MDD Condition	
a) Cohesion (kN/m^2)	18
b) Angle of Shearing Resistance(ϕ)	34°
ii). Saturated Condition	
a) Cohesion(kN/m^2)	0
b) Angle of Shearing Resistance	21°
Free Swell Ratio	0.613
CBR Value (%)	
i)Unsoaked Condition	20.4
ii)Soaked Condition	0.2
Coefficient of Permeability, k (m/s)	0.35×10^{-5}

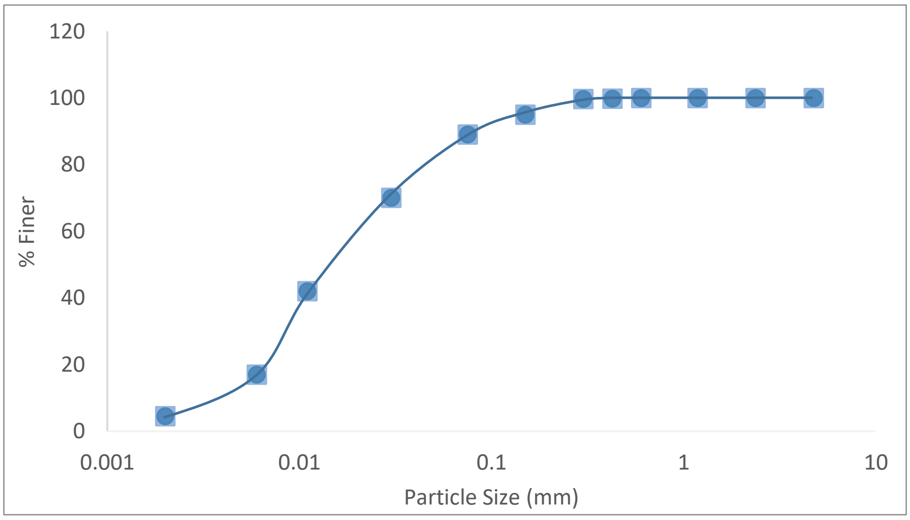

Fig.1. Grain Size Distribution Curve for Fly Ash

The compressibility characteristics of fly ash specimens prepared at OMC-MDD are determined in saturated state by conducting one dimensional consolidation tests in oedometer as per IS: 2720 (Part XV)-1965.The coefficient of consolidation (Cv) under varying normal pressures is determined by Taylors Square Root of Time fitting method. Compression Index, Cc is obtained as the slope of the straight line portion of e- $\log_{10} \sigma$ curveand is presented in Fig 3. Coefficient of consolidation and compression index of fly ash are presented in Tables 2 and 3.

Table 2. Coefficient of Consolidation of Fly Ash

Consolidation Pressure(kN/m^2)	t_{90} (s)	C_v(m^2/s)	Average C_v (m^2/s)
160	2.89	4.80 × 10^{-5}	
320	12.25	1.12 × 10^{-5}	2.17 × 10^{-5}
640	24.01	0.567 × 10^{-5}	

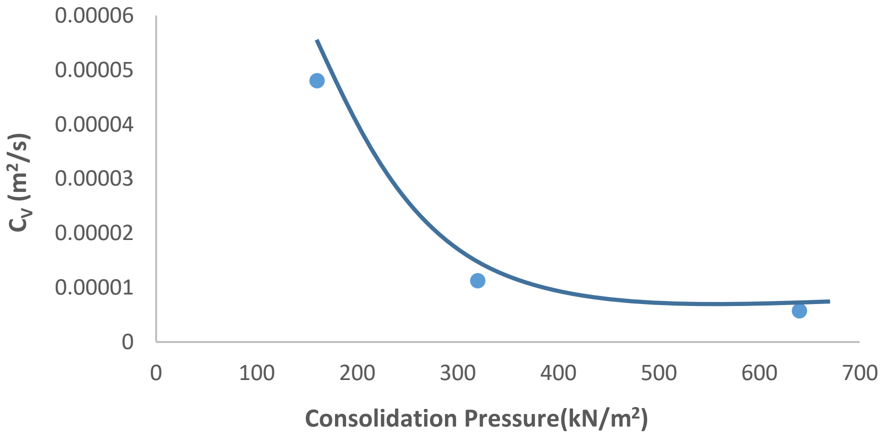

Fig.2. Variation of C_v with Consolidation Pressure for Fly Ash

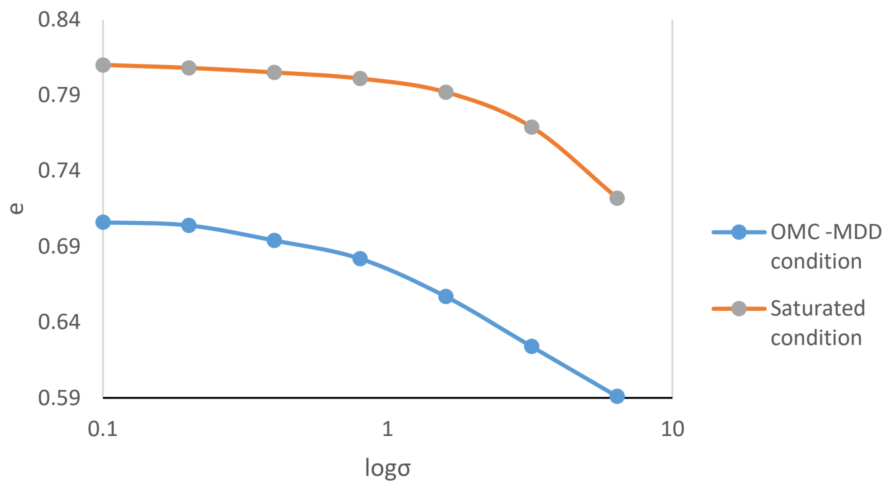

Fig. 3. Compression Indices of Fly Ash in OMC –MDD and Saturated conditions

Table 3. Compression Indices of Fly Ash

Soil Condition	C_c
Compacted at OMC-MDD	0.113
Saturated After Compacting at OMC-MDD	0.165

3 Discussion

The results indicate that the Maximum Dry Density of the fly ash (1.3g/cc) is much less than Maximum Dry Density of conventional construction materials (Sand- 1.8g/cc and Moorum-2.0g/cc). Fly ash in OMC-MDD state has an angle of shearing resistance of 34° and hence, satisfies the requirements of fill material given by Jones (1985). In saturated state, fly ash has low angle of shearing resistance (21°). The value of CBR decreased from 20.2 % in OMC-MDD compacted state to 0.2% in saturated state. Hence it shall not be used as highway construction material in water logged/heavy rainfall areas.From Fig.2, it is observed that the coefficient of consolidation is decreased with increase in consolidation pressure. The study revealed that fly ash has compression index (Cc) value in saturated state as 0.165, which is in the range of value of compression index of commonly used fill material of embankments, i.e low compressible clays(Cc= 0.14-0.23)

4 Conclusions

Based on the experimental studies conducted on Fly Ash in the present work, the following conclusions are drawn.

1. Fly Ash being light weight material compared to conventional fill material (Sand and Moorum) by about 27-35%, is advantageous in construction of embankments on weak subgrades.
2. Fly ash shall be avoided for use in the construction of embankments in water logged areas as it drastically loses CBR value from 20.2% in OMC-MDD state to 0.2% in soaked state.
3. Fly ash can be used as a fill/backfill material in retaining structures due to its high angle of internal friction of 34^0 in OMC-MDD compacted state, provided the material is not subjected to submergence.
4. The compression Index of Fly Ash (0.165) is in the range of compression index of commonly used embankment fill material, i.e., low compressible clay and thus justifies its use in embankment construction.

References

1. Boominathan A., Hari S.: Liquefaction strength of fly ash reinforced with randomly distributed fibers", Soil Dynamics and Earthquake Engineering 22 ,1027–1033(2002).
2. Chu, T.Y., Davidson, D.T., Goecker, W.L., Moh, Z.C.: Soil stabilization with lime flyash mixtures: Preliminary studies with silty and clayey soils. Highway Res. Board Bulletin 108, 102-112 (1955).
3. Ghosh, A., Subbarao, C.: Tensile strength bearing ratio and slake durability of class F fly ash stabilized with lime and gypsum, ASCE 18 (1), 18-27 (2006).
4. Goecker, W.L., Moh, Z.C., Davidson, D.T., Chu, T.Y.: Stabilization of fine and coarse-grained soils with lime-fly ash admixtures. Highway Res. Board Bulletin 129, 63-82 (1956).
5. Gray, D.H., Lin, Y.K.: Engineering properties of compacted fly ash. ASCE 98 (4), 361-380 (1972).
6. IS 2720: Method of test for soils, Bureau of Indian Standards, New Delhi.
7. Manjesh, L., Ramesh, N.H. Kumar Mohan, Sivapullaiah, V.P.: CBR values of soil flyash mixture for road construction. Proceedings of Indian Geotechnical Conference, Roorkee, pp. 451-454 (2003).
8. Prakash K. and Sridharan, A.:A geotechnical classification system for coal ashes. ICE Proceedings Geotechnical Engineering. 159(2), 91-98 (2006).
9. PrasanthNayak, Sagarika Panda, Rakesh Kumar Jena.: Stabilization of soil subgrade using fly ash-an industrial waste, Infokara Research journal Vol 8(8), (2019).
10. Rai Bahadur Reang and Sujit Kumar Pal: Strength behaviors of the clayey, silt soil mixed with fly ash and sand, Proceedings of Indian Geotechnical Conference, December 15-17, Chennai (2016).
11. SanuVasudevan, T. V. and Jaya V.: Influence of organic content on fly ash stabilisation of clay, Proceedings of Indian Geotechnical Conference, December 15-17, Chennai (2016).
12. Satyanarayana Reddy and Moorthy, N.V.R.: Potential of rock flour for use in reinforced soil constructions. Journal of South East Asian Geotechnical Society, pp.148-152 (2002).
13. Shenbaga. R. Kaniraj,Gayathri V.: Geotechnical behavior of fly ash mixed withrandomly oriented fiber inclusions. Geotextiles and Geomembranes 21, 123-149(2003).
14. Sivapullaiah P. V., Prashanth J. P. and Sridharan A.: Effect of fly ash on the index properties of black cotton soil. Soils and Foundations, 36(1), 97-103 (1996).

15. Sivapullaiah P. V. and Anil Kumar Sharma.: Ground granulated blast furnace slag amended fly ash as an expansive soil stabilizer. Soils and Foundations, 56(2), 205-212 (2016).
16. Sridharan, A.: Physical, chemical, and engineering properties of Indian coal ashes. Proc., National Seminar on Utilization of Fly Ash in Water Resources Sector,Central Soil and Materials Research Station, New Delhi, India, 15–28 (2001).
17. Viskochil, R.K., Handy, R.L., Davidson, D.T.: Effect of density on strength of lime-flyash stabilized soil. Highway Research Board Bulletin 183, 5-15 (1957).