A Study on the Influence of Coarse and Fine Grained Soils on the Strength Characteristics of Fly Ash

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Abstract: ***Class F fly ash is the solid residue by product produced by coal-burning electric utilities. They are usually disposed of together as a waste in utility disposal sites with a typical disposal rate of 80% fly ash and 20% bottom ash. Direct use of these materials in construction projects consuming large volumes, such as landfills, highway embankment construction etc., not only provides a promising solution to the disposal problem, but also an economic alternative to the use of traditional materials. Samples of class F fly ash were collected from utility power plant (NTPC) in Vijayawada and tested for their mechanical properties (compaction, direct shear and plate load test). Three mixtures of fly ash with different mixture ratios(i.e., 50% and 100% fly ash content by weight) both fine grained soil (clay) and coarse grained soil(sand) combined with ratios of lime (5% and 10%) added as binder were prepared for testing. Tests results indicated that ash mixtures compare favourably with fly ash mixture with fine grained soils and with 10% addition of lime.***

Keywords: Expansive Soil, Coarse Grained Soil, Fine Grained Soil, Montmorillonite, Flyash, Lime

1. Introduction

Generation of large volumes of pulverized fuel ash (PFA) by thermal power plants (TPPs) has become a subject of serious concern. The ash generation by coal/ lignite thermal power plants has increased from 40 Million tons/yr. during 1993-94 to 160 Million tons during 2009-10 and is projected to increase to 275 Million tons/yr. by 2016-17 and 600 Million tons/yr. by 2031-32.

On one hand management of such a huge quantum of pulverized fly ash (PFA) is a challenge and on the other hand there are a large number of low lying areas, abandoned quarries/laterite mines etc. in the vicinity of thermal power plants.

Coal/Lignite based Thermal Power Generation has been the backbone of power capacity addition in the country. Indian coal is of low grade with ash content of the order of 30-45 % in comparison to imported coals which have low ash content of the order of 10-15%.

1.2 Definitions

Pulverized fuel ash (PFA) and fly ash (FA), the both terms refer to and include all group/ type/ kind of ash generated at coal/ lignite fired thermal power plants. These include ESP dry fly ash, economizer ash, preheater ash, bottom ash, pond ash, mound ash.

Properties	Fly ash
Bulk Density	0.9-1.5
Specific Gravity	1.6-2.6
MDD	0.9-1.6
OMC (%)	18.0-40.0
C (kN/m^2)	Negligible
Φ°	28-42
Coefficient of consolidation	1.80×10^{-5}-2.20×10^{-4}
Compression index c_c	0.05-0.40
K (cm/sec)	8×10^{-6} - 7×10^{-4}
Clay fraction	01 to 10
Silt fraction	15-75
Sand fraction	10 to 80
Gravel fraction	0-5
C_u	3.1-10.7
Plasticity	Non-plastic
Shrinkage limit	Very low
Grain size	Silty/sandy
Clay content	Negligible
FSI	Very low
Classification	Sandy silt to silty sand

ESP dry fly ash (ESP DFA): The ash that is collected from the flue gases by means of electrostatic precipitator (ESP) or bag filters or other means and is in a dry condition.
Economizer ash (EA): The ash collected in the economizer at ESP area of a Thermal Power Station.
Pre-heater ash (PHA): The ash collected in the pre-heater at ESP area of a Thermal Power Station.
Bottom ash (BA): The ash that is collected at the bottom of the boiler of a Thermal Power Station.
Pond ash (PA): The PFA (or FA) i.e. ESP-DFA, EA, PHA, BA etc. mixed together, transported to ash pond area through water slurry or otherwise and deposited in ash pond in the mix condition is known as pond ash (PA).
Mound ash (MA): The PFA (or FA) i.e. ESP-DFA, EA, PHA, BA etc. mixed together, transported to ash deposition

area in dry or moist condition through conveyer belt or other means and deposited together in the mixed condition in the form of a mound is known as mound ash.

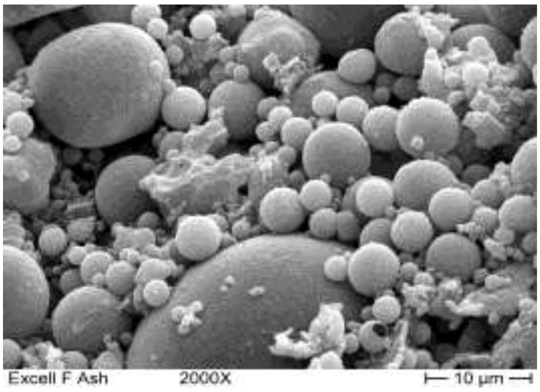

Figure: Microscopic view of fly ash particles

2. Review of Literature

2.1 Methods of Recognizing Expansive Soils

Grouped into three categories, following are the methods of recognizing expansive soils:

- Mineralogical identification
- Indirect methods, such as soil suction, activity and index properties
- Direct measurement.

2.2 Stabilization of Expansive Soil

Amit S. Kharade1, Vishal V. Suryavanshiare studied and investigation done on "waste product Bagasse ash" from sugar industry can be used as stabilizing material for expansive soils" in 2014. The effective percentage replacement of Bagasse ash was found to be 6%. The results improved at 6% replacement are as follows – The maximum dry density increased by 5.8%, California bearing ratio (CBR) increased by 41.52% and Compressive strength increase by 43.58%.

A.T.Manikandan, M.Moganraj studied on "consolidation and rebound characteristics of expansive soil by using lime and Bagasse ash" in April 2014, based on the test results in this study reveals that a series of liquid and plastic limit tests were performed on the untreated and Bagasse ash - Lime treated soil samples. It is observed that as the increases in Bagasse ash content with Lime, there is a marked reduction in liquid limit whereas plastic limit is increases.

Akshaya Kumar Sabat Experimented on "Utilization of Bagasse Ash and Lime Sludge for Construction of Flexible Pavements in Expansive Soil Areas" in 2013 the following conclusions are drawn from this study. The addition of Bagasse ash to expansive soil decreases the MDD and increases the OMC of the expansive soil irrespective of the percentage of addition of Bagasse ash. The UCS and soaked CBR are observed to have maximum values corresponding to the mix having proportion of, soil 76%,bagasse ash 8% and lime sludge 16%.The optimum proportion of soil: Bagasse ash: lime sludge is found to be 76:8:16.The swelling pressure goes on decreasing with addition of both Bagasse ash and lime sludge.

N. K. Ameta D.G. M. Purohit, A. S. Wayal are studied on "Characteristics, Problems and Remedies of Expansive Soils" of Rajasthan, India in 2007 Suggested Remedies for Swelling Soils are as follows. The swelling soil causes due to its expansive nature with water cracks are formed in buildings, canal lining etc. various suggestions to overcome the problem is as under. Provide CNS layer.

Dr. D S V Prasad, Dr. G V R PrasadaRaju, M Anjan Kumar studied on "Utilization Of Industrial Waste In Flexible Pavement Construction" in 2009 have made an attempt to use sand soil as sub grade, murrum and fly ash as sub base soils, waste plastics and waste tyre rubber as reinforcing materials in sub base soils, WBM Grade - 2 as base course in the flexible pavement system. It is observed from the results of CBR tests that for murrum and fly ash materials reinforced with different percentages of waste plastics, the optimum percentages were equal to 0.30 % for murrum and 0.40 % for flyash.

C. Rajakumar, T. Meenambal, P. D. Arumairaj done a team work on "California Bearing Ratio Of Expansive Sub grade Stabilized With Waste Materials"in2014 Based on the experimental studies the following conclusions were drawn. Sub grade soil used in this project was classified as clay of high plasticity. The soaked CBR value of untreated soil is 1.63% and 2.24% under both light and heavy compaction and hence it requires to be stabilized.CBR values increased for 4%, 8%, 12%, 16%,20% of Coal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations with uniform proportions. The UCC strength also increased for 4%, 8%, 12%, 16%, 20% of Coal Ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations with uniform proportions.

G Radhakrishnan Dr M Anjan Kumar and Dr GVR PrasadaRaju done a study on "Swelling Properties of Expansive Soils Treated with Chemicals and Fly ash" in 2014 the following conclusions are drawn based on the present laboratory study. Engineering Properties of the collected expansive soil samples indicate that soil samples comes under CH group. The Differential Free Swell value of the soil is 140%, indicating that the soil is highly expansive. Consistency limits indicate that the soil is high plasticity. The Swelling Pressure value is very high of the order of 295KPa. From the experimental study it is observed that the treatment of the expansive soil with Aluminium Chloride (AlCl3) and fly ash at 1% and 10% respectively is more effective than the other.

3. Objective and Methodology

3.1 Objective

To assess the suitability of modified fly ash as land fill material by using coarse grained and fine grained soils.
This can be done by following the steps noted below.

1) To enhance the properties of the fill by stabilizing the fly ash using a strengthening agent. Here lime which is

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hydrated is used as the stabilizer. The possible combinations of fly ash, coarse grained soil, fine grained soil, lime are taken in this process.
2) These combinations of fills are tested by conducting compaction test and shear test to know the viable replacement for soil.

In the present study, the fly ash was strengthened using coarse grained soil, that is locally available river sand and fine grained soil, that is locally available problematic expansive soil which is replaced when encountered in the infrastructural foundation systems.

3.2 Measurement of Shear Parameters of the Mixtures

Shear box tests were conducted to find shear parameters C and Ø in following cases.
1) Compacting fly ash, course grained soil (sand) and fine grained soil (expansive clay) in the lower and upper halves of the shear box.
2) Compacting fly ash, coarse grained soil and fine grained in the lower and upper halves of the shear box with ratios of lime added to them in variable percentages.

These tests were conducted in a shear box of size 60mm×60mm×20mm for evaluating the effect of friction mobilized at the interface of the fly ash to the fine grained soil and fly ash to the coarse grained soil and fly ash exclusively. The values of shear parameters C and Ø for fly ash with 0% lime added were 0.11kg/cm^2 and 24^0. Where C and Ø for coarse grained soil and fly ash with 0% lime added were 0.164kg/cm^2 and 43^0 and C and Ø for fly ash and fine grained soil with 0% lime added were 0.183kg/cm^2 and 38^0.

3.3 Variables Studied

1) 100 per cent of fly ash with 0%, 5% and 10% of lime added to the fly ash as binding agent as the lime combined with fly ash and the water present in the soil causes pozzolana reaction.
2) 50 per cent of coarse grained soil or sandy soil and 50 per cent of fly ash with 0%, 5% and 10% of lime added to the mixture of coarse grained soil and fly ash.
3) 50 per cent of fine grained soil or expansive soil and 50 per cent of fly ash with 0%, 5% and 10% of lime added to the mixture of fine grained soil and fly ash.

4. Experimental Study

4.1 Materials Used and Their Properties

In the following sections, the details of various materials and chemicals used in the laboratory experimentation are reported.

4.2 Soil and its Composition

The soil used was a typical black cotton soil collected from Madhavapatnam near Samalkota in East Godavari District, Andhra Pradesh State, India

4.3 Lime

The use of lime-soil mixture as a construction material has been known from ancient times in various parts of the world. Romans used it in their roads nearly 2000 years ago.

4.4 Soil – Lime Reactions

The addition of lime to a soil initiates a two stage reaction. Short-term reactions show their effect right after the addition of lime, while long term reactions are accompanied by a period of time. The short-term effect of the addition of lime to a clay soil is to cause flocculation and agglomeration of the clay particles. For cation exchange takes place between the metallic ions of the clay particles and the calcium ions of the lime. It is this process which is primarily responsible for the modification of the engineering properties of clay soils when they are treated with lime. When lime is added to a clay soil, it must first satisfy the affinity of the soil for lime, that is, ions are adsorbed by clay minerals and are not available for pozzolana reactions until this affinity is satisfied. Because this lime is fixed in the soil and is not available for other reactions, the process has been referred to as lime fixation. The lime fixation point corresponds with the point where further addition of lime does not bring about further changes in the plastic limit. This therefore is the optimum addition of lime needed for maximum modification of the soil. Beyond this point excess lime can only produce cementations compounds, which bind the flocculated particles and develop extra strength.

5. Discussion on Results

5.1 Laboratory Test Results

In the laboratory, index tests and strength tests were conducted by using different percentages of fly ash, coarse grained soil and fine grained soil with a view to determine the optimum percentage of lime.

Table: Showing properties of fine grained soil

S.No	Property	Properties
1	Specific gravity	2.67
	Grain size distribution	
2	Sand (%)	6.91
	Silt(%)	45.28
	Clay (%)	47.81
	Atterberg limits	
3	Liquid limt (%)	72

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	Plastic limit (%)	32.58
	plasticity index (%)	39.42
Compaction properties		
4	MDD (g/cc)	1.48
	OMC (%)	29.08
Shear Parameters		
5	Cohesion (kg/cm2)	0.632
	Angel of internal friction (ø)	1°

Table: Showing properties of coarse grained soil

S.No	*Physical Property*	*Test Result*
1	Specific gravity	2.62
2	Bulking value	35% at 8% of water
3	Fineness modulus	2.72

5.2 Compaction Properties

Compaction tests on different proportions of fly ash and fine grained soil and coarse grained soil, with different proportion of lime is presented and discussed in term of their OMC and MDD values.

The results show that with the increase in lime proportion up to 10% the OMC and MDD goes on increasing for all the cases, From this we can conclude that by the addition of lime to the fly ash, the lime is reacting with the silica present in the fly ash to form pozzolonic reaction.

Table: Comparison of Compaction Results of mixtures of FA + CG soil with % of lime

S.NO	Composition of Fill	OMC	MDD
1	COF 4	14.64	1.37
2	COF 5	15.44	1.41
3	COF 6	17.21	1.47

Table: Comparison of Compaction Results of mixtures of FA + FG soil with % of lime.

S.NO	Composition of Fill	OMC	MDD
1	COF 7	23.63	1.42
2	COF 8	25.56	1.47
3	COF 9	27.44	1.54

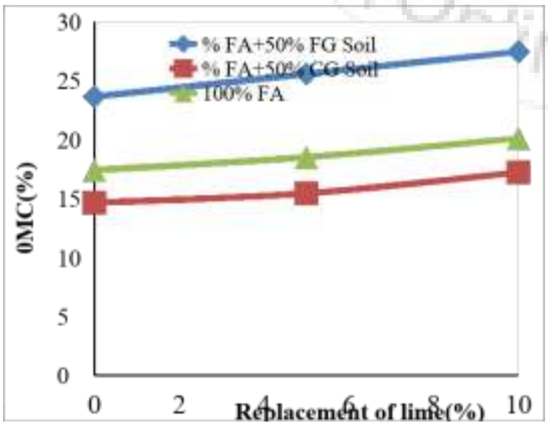

Figure: Comparison graph showing OMC's of mixtures of 100% fly ash, coarse grained soil and fine grained soils with percentages of lime.

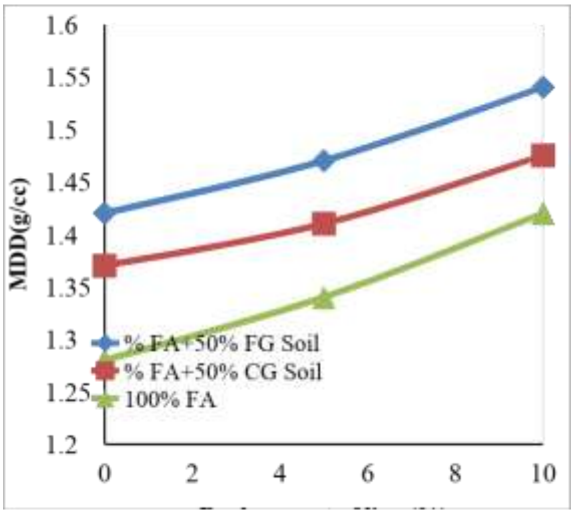

Figure: Comparison graph showing MDD's of mixtures of 100% fly ash, coarse grained soil and fine grained soils with percentages of lime

5.3 Direct shear results

Comparison of Shear Parameters of mixtures of 100% FA with % of lime.			
S.NO	COF	Cohesion (kg/cm^2)	Angle of Internal Friction(Ø)°
1	COF 1	0.11	24
2	COF 2	0.13	33
3	COF 3	0.15	40

Comparison of Shear Parameters of mixtures of FA + CG soil with % of lime			
S.No	COF	Cohesion (kg/cm^2)	Angle Of Internal Friction(Ø°)
1	COF 4	0.164	43
2	COF 5	0.172	49
3	COF 6	0.178	56

Comparison of Shear Parameters of mixtures of FA + FG soil with % of lime.			
S.No	COF	Cohesion (kg/cm^2)	Angle Of Internal Friction(Ø°)
1	COF 7	0.183	38
2	COF 8	0.195	43
3	COF 9	0.26	48

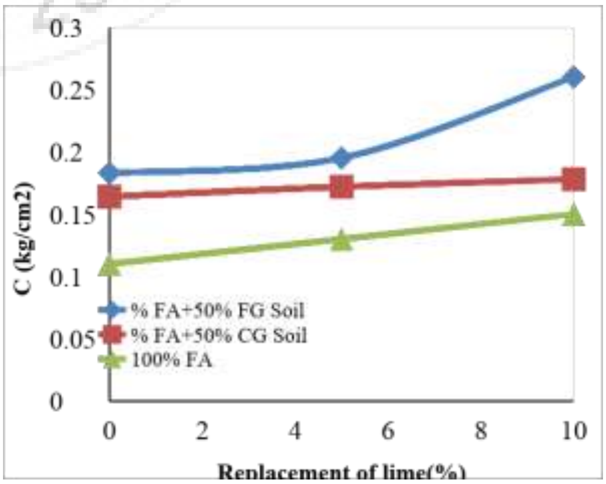

Figure: Comparison graph showing cohesion(C)'s of mixtures of 100% fly ash, coarse grained soil and fine grained soils with percentages of lime

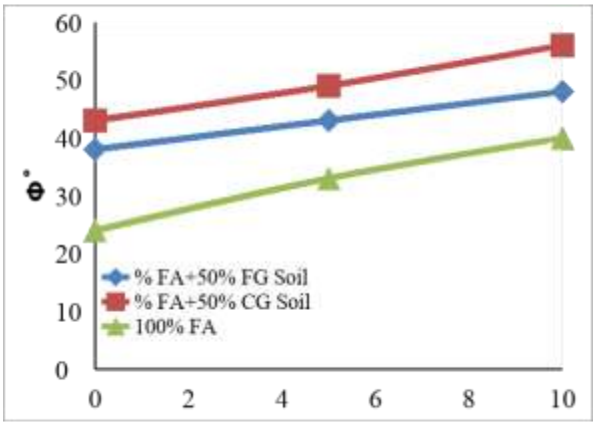

Figure: Comparison graph showing Angle of internal friction (Ø)'s of mixtures of 100% fly ash, coarse grained soil and fine grained soils with percentages of lime

6. Conclusions

1) There is a decrease in OMC, MDD & Cohesion at 100% of FA with increase in lime content from 0% to 10% compared to properties of virgin soil.
2) The % of decrease in OMC at 100% of FA is 40.2%, 36.4% & 30.9% at 0%, 5% & 10% lime contents respectively with comparison to virgin soil properties.
3) There is an increase in Angle of internal friction compared to virgin soil at any composition of fill.
4) We can observe that improvement in compaction as well as shear properties when Coarse Grained soil of 50% mixed with 50% of FA and then blended with lime with various percentages.
5) Also there is an increase in MDD, Cohesion, Angle of internal friction and decrease in OMC with increase in lime % from 0% to 10% for 50% of coarse grained soil mixed with 50% of FA.
6) At 10% lime with 50% coarse grained soil and 50% of FA there is an improvement in Angle of internal friction of 133%, cohesion of 61.8% compared to 0% lime with 100% of FA.
7) At 10% lime with 50% fine grained soil and 50% of FA there is an improvement in Angle of internal friction of 100%, cohesion of 136.4% compared to 0% lime with 100% of FA.
8) At every composition there is a decrease in OMC compared to virgin soil, for pure flyash with increase in lime content there is an increase in OMC, for coarse grained soil and flyash mix there is a decrease in OMC with increase in lime content.

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