Utilization of Fly Ash and Gravel Mixes in Road Construction as Sub Base Layer

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Abstract— Fly ash is an industrial waste that can have lot of advantages due to their coherent qualities. For their bulk utilization in constructional activities as a sub-grade, embankments, and fill materials and their geo-technical characterizations has been attempted. In this study three fly ashes have been collected from NTPC, RINL, SEIL and subjected for gradation, consistency, compaction, shear parameters, CBR, etc. They are also exposed for shear resistance at various moisture contents. From the test results it is identified that the three fly ashes are non-plastic, uncompressible and have low specific gravities (7.8-2.1). They occupy less dry densities (1.11g/cc – 1.28 g/cc) with wide variation in their OMC (22-36%). They can also possess high shear resistance values with wide variation of moisture contents. Due to low density, high shear resistance they can be used as fill, embankment and sub-grade material.

Key words: Road Construction, Utilization of Fly Ash and Gravel Mixes

I. Introduction

In the recent years search for alternate materials for the constructional activities has been gaining importance. Some of alternate materials are Fly ash, Pond ash, RHA, GGBFS, Slag, Crusher dust, etc. Disposal of these materials requires huge quantities of land and searching for various solutions are in progress. One such is utilization of these in geotechnical constructional activities such as fill, sub-grade and sub-base material.

Fly ash is an industrial waste obtained by burning of coal from thermal power plants. Annual production of Fly ash touches 200 MT. Fly ash has inherent qualities like non-plastic, incompressible and semi-pervious nature and pozzolanic characterization helps the practicing engineer to use in constructional activities. Some of the researchers finding on the utilization of Fly ash in geotechnical applications are Boominathan et.al (1996,1999), Sridharan et.al (1997,1998), Ramakrishna et.al (2001), Prabhakar et.al (2003), Smith (2005) etc. In the present study three Fly ashes have been collected from Visakhapatnam region and tested for various geotechnical characteristics such as gradation, compaction, strength, seepage, etc., and also studied their utilization in constructional activities.

II. Objectives of Present Study

1) To study the geotechnical characteristics like gradation, plasticity, compaction, CBR, angle of shearing resistance, etc.
2) To study the variation of shear parameters at different moulding water contents.
3) To study the suitability of fly ashes in geotechnical applications as sub-grade, fill material, embankment, etc.

III. Scope of Present Study

Three fly ashes collected from Visakhapatnam region including NTPC fly ash, RINL fly ash, and SEIL fly ash. For their utilization in geotechnical construction in bulk quantities, suitable tests like CBR, compaction, plasticity, etc. have been performed and their results were verified.

IV. Review of Literature

A. *Production of Fly Ash*

Fly ash is produced by burning of coal. Around 75-85% of the ash produced from the combustion of the coal is carried out of the furnace with the flue gases and is extracted by electrostatic or cyclonic precipitator. This is known as fly ash. ASTMC 618-94a (1995) defines the fly ash as a finely divided residue that resulted from the combustion of ground or powdered coal. The remaining portion of the ash produced falls into the hopper placed at the bottom of the furnace. This ash is called as bottom ash. Fly ash is composed of finer particles and it can be easily blown off by air and hence the name fly ash. The bottom ash is composed of primarily coarser and heavier particles. In countries like India and Japan quality of coal is poor and they produce ash as much as 20 – 30% of their weight on burning. Coal in USA, UK and Canada produce ash only about 10% of their weight (Sridharan et al., 1996).

B. *Properties of Fly ash*

A property of fly ash not only varies from different thermal power plants but also from the same thermal power plant. The property of fly ash depends upon the following factors (Raymond, 1961; Toth et al., 1988 and; Uppal and Dhawan 1968).

- Type of coal used
- The treatment to which coal has been subjected prior to combustion
- The method of combustion
- Furnace temperature
- Amount of air circulation
- Collection and storage places adopted
- Method of disposal

V. Methodology

A. *Introduction*

In this chapter a brief description of the experimental procedures adopted in this investigation and the methodology adopted during the course of the study are briefly presented.

B. *Material Used*

The materials used in this investigation are:

- NTPC Flyash
- RINL Flyash

- SEIL Flyash

C. *Laboratory Testing*

1) *Properties of Flyash*

The following tests were conducted on the flyash. The index and engineering properties of flyash were determined.

- Grain size analysis confirming (IS: 2720-part 4, 1985)
- Consistency limits or Atterberg's Limits using Uppals method confirming (IS: 2720-part 5, 1985)
- Compaction test confirming (IS: 2720- Part 8: 1983)
- California bearing ratio test confirming (IS: 2720- Part 16: 1987)
- Direct Shear Test (IS: 2720- Part 17 : 1986)

2) *Grain Size Analysis: (IS: 2720- part 4, 1985)*

Sieve analysis was carried out using a set of standard I.S.Sieves. The sample was oven dried and placed on the top of the sieve set and shaken by hand. The fine fraction that passed through 75 micron sieve was taken and hydrometer analysis was carried out in 1000 ml for using the required quantuty of sodium Hexametaphosphate as dispersing agent. The test was carried out according to IS: 2720- part 4, 1985.

A known quantity of oven dried sample has taken in a set of dieves i.e., 4.75mm, 2.36, 1.18 mm, 600 µ, 425µ, 300µ, 150µ, 75µ arranged in an ascending order and shake for 10 minutes to 15 minutes on a sieve shaker. The weight retained on each sieve has obtained and their corresponding percentage finer has detrmined. Therefore from the graph plotted between percentage finer as Ordinate and Particle size (D in mm) as abcissa, mean particle size D_{10}, D_{15}, D_{30} ,D_{50}, D_{60}, D_{85}, D_{90} are determined similarly the Coefficeint of Uniformity (C_u) and Coefficient of Curvature (C_c) also be determined.

3) *Consistency Limits (IS: 2720-part 5, 1985)*

a) Liquid Limit

The liquid limit test was conduted as per I.S:2720 (part - v)-1970. The test is conducted on soil after passing 425 micron I.S. Sieve using casagrande apparatus.

b) Plastic Limit

The plastic limit test was coducted as per I.S:2720 (part - v)-1970.

4) *Compaction: (IS: 2720- Part 8: 1983)*

A known quantity of oven-dried sample of Fly ash-Soil mixes with various percentages of water was mixed and transferred into CBR mould with a rammer of 4.9 kg, 5 layers and each layer subjected to 56 blows. For each set of results bulk unit weight, dry unit weight and corresponding water contents. A graph has been developed between water content and dry unit weights known as compaction curve. From the compaction curve, optimum moisture content and maximum dry density was obtained. The same procedure is repeated for various gradation mixes.

5) *California Bearing Ratio Soaked (IS: 2720- Part 16: 1987)*

The samples are prepared at Optimum Moisture Content is conducted as per I.S:2720 (part-xvi) 1987. Specimen after preparation were moist cured in closed desicators at room temperature for 0, 7,30 days and at end of each curing period, specimens of a correspond mix were taken out and tested for their.

The laboratory CBR apparatus consists of consists of a mould 150 mm diameter with a base plate and a collar, a loading frame with the cylindrical plunger of 15 mm diameter and dial gauges for measuring the expansion on soaking and the penetration values.

Briefly the penetration tests consists of causing a cylindrical plunger of 50 mm diameter to penetrate a pavement component material at 1.25 mm/min. the load value to cause 2.5 mm and 5.0 mm penetration are recorded. These loads are explained as percentage of standard load value at respective deformation levels to obtain CBR values. The standard load values obtained from average of a large number of tests on crushed stones are 1370 and 2055 kg (70 and 105 kg/cm^2) respectively at 2.5 and 5.0mm penetration.

The specimen in the mould is subjected to 4 days soaking and the swelling and water absorption values are noted. The surcharge weight is placed on the top of the specimen in the mould and the assembly is placed under the plunger of the loading frame. The load values are noted corresponding to penetration values of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12.5 mm. the load penetration graph is plotted. Alternatively, the load values may be converted to pressure values and plotted against the penetration values.

Fig. 1: CBR Apparatus

Two typical types of curves may be obtained. The normal curve is with convexity upwards as per specimen number 1 and loads corresponding to 2.5 and 5.0 mm penetration values are noted. Sometimes a curve with initial upward concavity is obtained, indicating the necessity of the correction as per specimen number 2. In this case, the corrected origin is established by drawing a tangent AC for steepest point on the curve. The load values corresponding top 2.5 and 5.0 mm penetration values from the corrected origin C are noted.

The causes for initial concavity of the load penetration curve calling for the correction in the origin are due to:

- The bottom surface of the plunger or the top surface of the soil specimen not being truly horizontal, with the result the plunger surface not being in fully contact with the top of the specimen initially.
- The top layer of specimen being too soft or irregular.

The CBR values are calculated using the relation

$$CBR\% = \frac{[\text{Load (or pressure)sustained by the specimen at 2.5 or 5.0 mm penetration}]}{[\text{Load sustained by standard aggregates at the corresponding penetration levels}]}$$

Normally the CBR value at 2.5 mm penetration that is higher than that at 5.0 mm is reported as the CBR value of the material. However, if the CBR value obtained from the test at 5.0 mm penetration is higher than that at 2.5 mm, then the test is to be prepared for checking. If the check test again gives similar results, the higher value obtained at 5.0 mm penetration is reported as the CBR value. The average CBR value of three test specimens is reported to the first decimal place, as the CBR value of material. If the variation in the CBR value between the three specimens is more than the prescribed limits, tests should be repeated on additional three samples and the average CBR value of six specimens is accepted.

6) Direct Shear Test (IS: 2720- Part 17, 1986)

Samples of Crusher Dust are taken as oven dried and weighed as per the volume of Direct Shear mould. Now the sample is filled in three layers in the mould and compacted for 25 blows. Before placing the sample in Direct Shear mould, porous Shearing plates are kept perpendicularly facing their grooves at top and bottom of the sample. Entire set up is now kept in the container seating and a proving ring is attached and a surcharge load of 0.5, 1.0, 1.5 and 2.0 kg/cm^2 are kept simultaneously for samples at various water contents. Now a load is applied in the horizontal direction at a strain rate of 1.25mm/min and observed for shearing in the sample. This procedure is repeated for different normal pressures.

7) Coefficient of Permeability: Falling Head Permeability Test (IS: 2720- Part 17: 1986)

In the Falling Head Permeability test as per IS:2720- Part 17:1986, Crusher Dust samples for various locations is allotted to saturate 100% by allowing water through the entire sample grain to grain saturation at its Dry Density. At various heads the Coefficient of Permeability values are calculated using the given relation:

$$K= (a.L/A.t) * In*(h_o/h_t)$$

Where,
k = coefficient of permeability (cm/sec)
a = area of burette standpipe (cm^2)
L = length of specimen (cm)
A =area of specimen (cm^2)
t = elapsed time of test (sec)
h_0 = head at beginning (time =0) at test (cm)
h_t= head at end (time=t) of test (cm)

VI. RESULTS

A. Introduction

Fly ash is an industrial waste product obtained from thermal power plants by burning of coal. Fly ash production touches more than 150 MT annually in India. Similarly coal yields 36% of waste in the form of fly ash. To utilize these waste products in geotechnical applications as sub-grade, fill material, etc. three fly ashes were collected from source of NTPC Parawada, RasthriyaIspat Nigam Limited (RINL) Steel Plant and Steel Exchange India Limited (SEIL) steel plants from Visakhapatnam. These three fly ashes subjected for various geotechnical characterizations such as gradation, consistency, compaction, strength, seepage and compression, etc, as per IS 2720.

B. NTPC Flyash

Flyash was collected from NTPC Paravada in Visakhapatnam, Andhra Pradesh and laboratory study was carried out for salient geotechnical characteristics such as gradation, Atterberg limits, compaction and strength. The properties of fly ash are shown in table 6.1 to 6.5 and fig 6.1 to 6.3.

1) Gradation Curve

The test was carried out according to IS: 2720(part-IV).

Sieve Size (mm)	Fines (%)
4.75	100
2.36	100
1.18	100
0.6	100
0.425	100
0.3	99
0.15	89
0.075	72
0.050	58
0.04	50
0.02	30
0.010	14
0.006	5
0.002	0

Table 1: Gradation sizes of NTPC Flyash

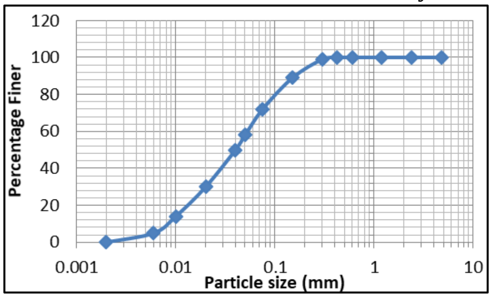

Fig. 2: Gradation Curve of NTPC Flyash

Coefficient of uniformity: Cu = 6.42; Coefficient of curvature: Cc = 0.88.

From the physical characteristics of Fly ash it is observed that, it is light grey in colour, majority of Fly ash particles pass through 425µm sieve consisting of fine sand size and silt size particles. From the compressibility characteristics it is identified as non- plastic and very low compressive in nature.

2) Compaction test

To know the compaction characteristics of fly ash, IS heavy compaction test was performed as per IS 2720 part -8, 1983. At every moisture content dry density was calculated using the formula, $\Upsilon_d = \Upsilon/(1+\acute{\omega})$ and the results are shown in table 2 and fig 3.

S. No.	Moisture Content (%)	Dry density (g/cc)
1	5	1.1
2	10	1.17
3	12.5	1.2
4	15	1.23
5	21	1.275
6	25	1.26
7	30	1.22
8	35	1.16
9	40	1.07

Table 2: Compaction Characteristics of NTPC Flyash

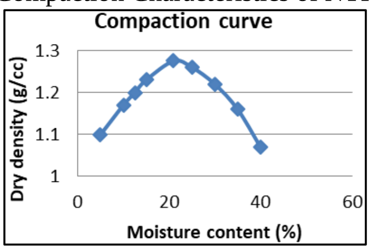

Fig. 3: Compaction curve of NTPC Fly ash

From the test results it was identified that the maximum dry density (MDD) as 1.28 g/cc and optimum moisture content (OMC) as 21%. It is also seen that attainment of lower maximum dry density and high moisture content are due to nature and specific gravity of fly ash particles. From the compaction curve it can also be seen that fly ash attains lower dry densities with wide variation in moisture contents.

3) Geotechnical properties of NTPC Flyash

Property	Values
Grain size distribution:	
Gravel (%)	0
Sand (%)	28
Fines (%)	72
Silt(%)	72
Clay(%)	0
Consistency:	
Liquid Limit (%)	28
Plastic Limit (%)	NP
I.S Classification	MLN
Specific gravity	2.1
Compaction characteristics:	
Optimum moisture content (OMC)(%)	21.0
Maximum dry density (MDD) (g/cc)	1.28
Shear parameters:	
Angle of shearing resistance(deg)	34
California bearing ratio (CBR) (%) (Soaked condition)	5.0

Table 3: Geotechnical properties of NTPC Flyash

4) Chemical composition of Flyash

Compound Formula	Percentage
SiO_2	59.83
Al_2O_3	30.48
CaO	1.74
MgO	0.86
TiO_2	6.91
V_2O_5	0.09
ZnO	0.09

Table 4: Chemical composition of Flyash

5) Shear Parameters of NTPC Fly ash at Various Moisture Contents

To know the shear parameters like ϕ (angle of shearing resistance)at various moisture contents can be determined by compacting fly ash samples at their respective moisture contents 10%, 12%, 14%,…….30% and direct shear tests were performed as per IS: 2720- Part 17 : 1986 and the results are shown in table 5 and figure 4.

Water Content (%)	10	12	14	16	18	20	21	22	24	26	28		20	21	22	24	26	28	30
Angle of Shearing Resistance (Degree)	27	28	30	31	32	33	34	33	32	30	33	34	33	32	32	28	26		

Table 5: Shear Parameters of NTPC Fly ash

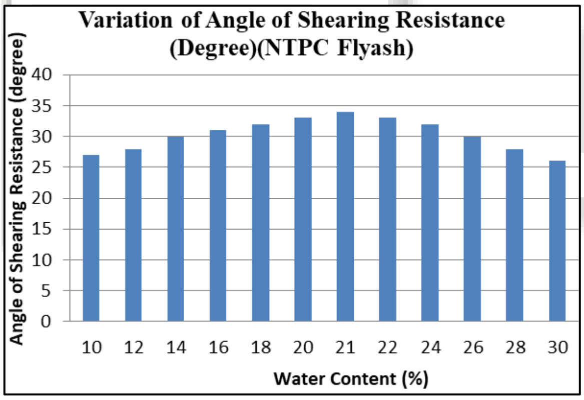

Fig. 4: Variation of Angle of Shearing Resistance of NTPC Fly ash

From the test results it is identified the angle of shearing resistance values are decreasing with increase in moisture content (wet condition); the same trend was also identified for decreasing moisture contents (dry conditions). The maximum angle of shearing resistance (34°) was obtained at their optimum moisture content (21%). From the test results it is also observed that if the moisture contents are nearing to OMC on wet as well as dry side (18-24%) the angle of shearing resistance values are 32-33° which are nearer to maximum values obtained at their OMC. Whereas further wet side of OMC i.e.24% - 26 % the value is varying from 32-30° and on drier side i.e. 16-12% the angle of shearing resistance value obtained as28°-31°. The loss of angle of shearing resistance on dry side is less than that on wet side but on wet side at high moisture contents the fly ash particles maintain reasonable values of angle of shearing resistance. Hence from the test results NTPC flyash can withstand high angle of shearing resistance (shear strength) for wide variation of moisture contents.

C. Rasthriya Ispat Nigam Limited (RINL)Flyash

1) Gradation Curve

The test was carried out according to IS: 2720(part-IV).

Sieve Size (mm)	Fines (%)
4.75	-
2.36	-
1.18	-
0.6	-
0.425	100
0.30	100
0.15	95
0.075	86
0.05	29
0.02	58
0.01	43
0.008	38
0.004	24
0.003	18
0.002	10
0.001	0
0.0009	0

Table 6: Gradation sizes of RINL Flyash

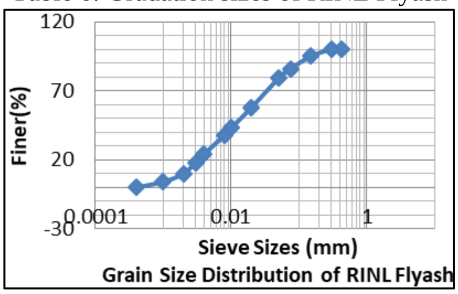

Fig. 5: Gradation Curve of RINL Fly ash

Coefficient of uniformity: Cu =11.5; Coefficient of curvature: Cc =0.63.

From the physical characteristics of fly ash it is observed that, it is dark grey in colour, majority of fly ash particles passes through425µm sieve consisting of fine sand sizes (14%) and silt sizes (86%) particles. From the compressibility characteristics it is identified as non- plastic and very low compressive in nature.

2) Compaction test

To know the compaction characteristics of fly ash, IS heavy compaction test was performed as per IS 2720 part -8, 1983. At every moisture content dry density was calculated using the formula, $\Upsilon_d = \Upsilon/(1+\omega)$ and the results are shown in table 7 and fig 5.

S. No	Moisture Content (%)	Dry density (g/cc)
1	5	1.02
2	10	1.035
3	15	1.052
4	20	1.07
5	25	1.084
6	30	1.099
7	36	1.11
8	40	1.099
9	45	1.08
10	50	1.06
11	55	1.058
12	60	1.01

Table 7: Compaction Characteristics of Fly ash

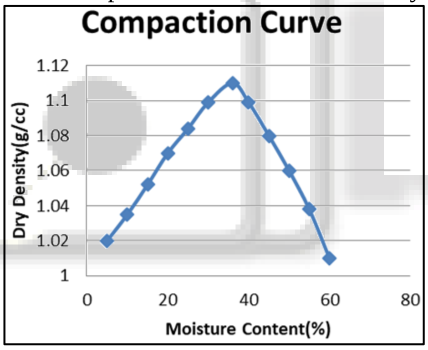

Fig. 6: Compaction curve of RINL Fly ash

From the test results it is identified that the maximum dry density (MDD) as 1.11gm/cc and optimum moisture content (OMC) as 36%. It is also seen that attainment of lower dry densities at high moisture content are due to nature and specific gravity of flyash particles. From the compaction curve it can also be seen that flyash attains lower dry densities with wide variation in moisture contents.

3) Geotechnical properties of RINL Flyash

Property	Values
Grain size distribution:	
Gravel (%)	0
Sand (%)	14
Fines (%)	86
Silt(%)	86
Clay(%)	0
Consistency:	
Liquid Limit (%)	52
Plastic Limit (%)	NP
I.S Classification	MLN
Specific gravity	1.9
Compaction characteristics:	
Optimum moisture content (OMC) (%)	36.0
Maximum dry density (MDD) (g/cc)	1.11
Shear parameters:	
Angle of shearing resistance(deg)	35
California bearing ratio (CBR) (%) (Soaked condition)	4.0

Table 8: Geotechnical properties ofRINL Flyash

4) Shear Parameters of RINL Fly ash Various Moisture Contents:

To know the shear parameters like ϕ (angle of shearing resistance) at various moisture contents can be determined by compacting fly ash samples at their respective moisture contents 10%, 12%, 14%,…….45% and direct shear test was performed as per IS: 2720- Part 17 : 1986 and the results are shown in table 9 and figure 7.

Water Content (%)	10	15	20	25	30	34	36	38	40	42	45
Angle of Shearing Resistance (Degree)	26	28	29	30	32	34	35	34	32	30	28

Table 9: Shear Parameters of RINL Flyash

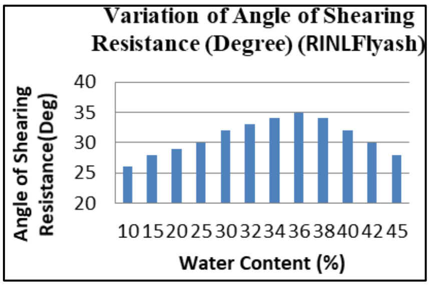

Fig. 7: Variation of Angle of Shearing Resistance of RINL Flyash

From the test results it is identified the angle of shearing resistance value is decreasing with increase in moisture contents; the same trend was identified for decreasing moisture contents also. The maximum angle of shearing resistance (35º) was obtained at its optimum moisture content (36%). From the test results it is also observed that the moisture contents nearing to OMC on wet as well on dry side (30-40%) the angle of shearing resistance values are 32-34º which are nearer to maximum values obtained at its OMC, whereas further wet side of OMC i.e. 40 % - 45 % the value is varying from 32-28º and on dryer side i.e. 30 % -15 % the angle of shearing resistance value obtained is 28º-32º. The loss of angle of shearing resistance on dry side is less than that on wet side but on wet side at high moisture contents the flyash particles maintain reasonable values of angle of shearing resistance. Hence from the test results RINL flyash can also withstand high angle of shearing resistance (shear strength) for wide variation of moisture contents.

D. Steel Exchange India Limited (SEIL) Flyash

1) Gradation Curve

The test was carried out according to IS: 2720(part-IV).

Sieve Size (mm)	Fines (%)
4.75	-

2.36	-
1.18	-
0.6	-
0.425	100
0.3	100
0.2	96
0.15	93
0.1	88
0.075	82
0.05	72
0.02	50
0.01	36
0.008	30
0.004	17
0.003	12
0.002	6
0.001	0

Table 10: Gradation sizes of SEIL Flyash

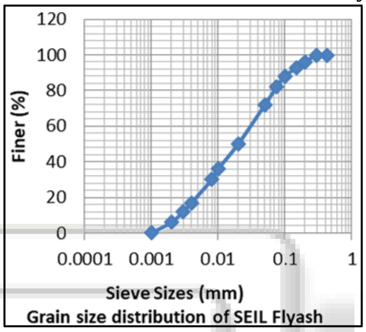

Fig. 8: Gradation Curve of SEIL Plant Flyash

Coefficient of uniformity: Cu =12.59; Coefficient of curvature: Cc =6.97.

From the physical characteristics of Flyash it is observed that, it is grey in colour, majority of Flyash particles pass through 425µm sieve consisting of fine sand size (18%) and silt size (82%) particles. From the compressibility characteristics it is identified as it is non- plastic and very low compressive in nature. From the compaction curve it can be seen that Flyash attains lower densities with wider variation in moisture contents.

2) Compaction test

To know the compaction characteristics of flyash, IS heavy compaction test was performed as per IS 2720 part -8, 1983. At every moisture content dry density was calculated using the formula $\Upsilon_d = \Upsilon/(1+\omega)$, and the results are shown in table 11 and fig 9.

S. No	Moisture Content (%)	Dry density (g/cc)
1	5	1.04
2	10	1.076
3	15	1.11
4	20	1.149
5	26	1.18
6	30	1.17
7	35	1.148
8	40	1.12
9	45	1.086
10	50	1.04

Table 11: Compaction Characteristics of SEIL Flyash

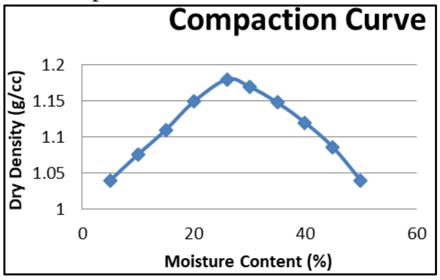

Fig. 9: Compaction curve of SEIL Fly ash

From the test results it is identified that the maximum dry density (MDD) as 1.18gm/cc and optimum moisture content (OMC) as 26%. It is also seen that attainment of lower dry densities at high moisture content are due to nature and specific gravity of fly ash particles. From the compaction curve it can also be seen that fly ash attains lower dry densities with wide variation in moisture contents

3) Geotechnical properties of SEILFlyash

Property	Values
Grain size distribution:	
Gravel (%)	0
Sand (%)	18
Fines (%)	82
Silt(%)	0
Clay(%)	0
Consistency:	
Liquid Limit (%)	38
Plastic Limit (%)	NP
I.S Classification	MLN
Specific gravity	2.0
Compaction characteristics:	
Optimum moisture content (OMC) (%)	26.0
Maximum dry density (MDD) (g/cc)	1.18
Shear parameters:	
Angle of shearing resistance(deg)	34
California bearing ratio (CBR) (%) (Soaked condition)	4.0

Table 12: Geotechnical properties of SEILFlyash

4) Shear Parameters of SEIL Flyash at Various Moisture Contents

To know the shear parameters like ϕ (angle of shearing resistance) at various moisture contents can be determined by compacting flyash samples at their respective moisture contents 10%, 12%, 14%,…….34% and direct shear test was performed as per IS: 2720- Part 17 : 1986 and the results are shown in table 13 and figure 10.

Water Content (%)	10	15	20	22	24	26	28	30	32	34
Angle of Shearing Resistance (Degree)	27	29	31	32	33	34	33	32	30	28

Table 13: Shear Parameters of SEIL Flyash

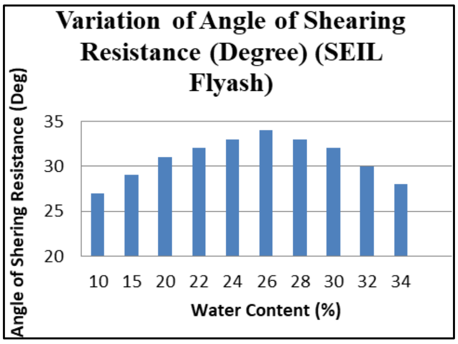

Fig. 10: Variation of Angle of Shearing Resistance of SEIL Fly ash

From the test results it is identified the angle of shearing resistance value is decreasing with increase in moisture content; the same trend was identified for decreasing moisture contents also. The maximum angle of shearing resistance (34°) was obtained at their optimum moisture content (26%). From the test results it is also observed that the moisture contents nearing to OMC on wet as well as dry side (20-30%) the angle of shearing resistance values are 31-34° which are nearer to maximum values obtained at their OMC. Whereas further wet side of OMC i.e. 30 % - 34 % the value is varying from 32-28° and on dryer side i.e. 20 % - 10 % the angle of shearing resistance value obtained is 31°-27°. The loss of angle of shearing resistance on dry side is less than that on wet side but on wet side at high moisture contents the fly ash particles maintain reasonable values of angle of shearing resistance. Hence from the test results SEIL fly ash can also withstand high angle of shearing resistance (shear strength) for wide variation of moisture contents.

VII. DISCUSSIONS

Three fly ashes NTPC, RINL and SEIL flyash are obtained from burning of coal. These are light grey to dark grey in colour. The variation of colour is due to the composition and location of coal and other characterization due to formation of coal. They are composed mainly of particles passing through 425µm IS Sieve out of which majority of the particles are passing through 75µm IS Sieve. NTPC flyash has 72% of fines, RINL 86% and SEIL has 88%. All these fly ashes have silt characteristics which can interact with moisture.

From consistency these three are non-plastic and attain flow consistency at 25mm penetration are in the range of 28, 38 and 52 for NTPC, RINL and SEIL plants respectively. Attainment of high flow consistency is due to fineness of particles.

The specific gravity of these three fly ashes are in the range of 1.8-2.1. The variation of specific gravity purely connected to mineralogical composition of fly ash. High specific gravities are due to domination of oxides of heavy minerals. From the density water content relationships NTPC fly ash attains maximum dry density 1.28g/cc whereas RINL fly ash has 1.11g/cc and their corresponding optimum moisture contents are 22 and 36 respectively and SEIL fly ash is in between these fly ashes. Again attainment of low dry density and high moisture contents are connected to the nature, composition of fly ashes from the test results of strength characterizations all these three fly ashes have attained more or less the same angle of shearing resistance i.e. 34-35° and CBR is in the range of 4-5%.

From all these three fly ashes it may say that these are non-plastic, incompressible having low dry densities and possess less variation in their strength values and can be used as sub-grade materials, fill and embankment material.

VIII. CONCLUSIONS

- These fly ashes are dominated by silt size particles and non-plastic and incompressible and their specific gravity is in the range of 1.8-2.1.
- They attained low maximum densities with wide variation of OMC are in the range of 1.11 to 1.28 g/cc and 22 – 36% respectively.
- Angle of shearing resistance at their maximum dry densities are 34-35°.
- These flyashes can withstand their shearing resistance values with wide variation of moisture content.
- Due to non – plastic and incompressible and semi-pervious, they can be like sand particles which can be replaced by flyash particles as a fill material, sub-grade material in construction.
- Due to light weight of these materials, there can be efficiently used as an embankment material with erosion control measures.

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