February 2016 IJESR Volume 4, Issue 2 ISSN: 2347-6532

GEO-ENGINEERING PROPERTIES OF FLY ASH

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ABSTRACT:

The aim of the Project is to find out the geo-engineering properties of fly ash, in geo-engineering field. The project describes the use of local fly ash in construction industry in a way to minimize the industrial waste such as fly-ash, slag etc can be effectively used in soil stabilization. If these materials can be used in highway or dam construction, it will be a great effort in minimizing the industrial pollution. Experiments are done in order to determine the geo-engineering properties of fly ash, which can taken account in the construction field. A brief comparison is made between fly ash and other soil properties which are used as sub-grade, base in Highway construction.

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1.INTRODUCTION

It is one of the residues formed in combustion, and consists of the fine particles that rise with the flue gases. Fly ash typically refers to ash formed during combustion of coal. The fly ash manufacture in India is around 100 million ton per year and ash ponds presently occupy nearly 64,000 acres of land. Occasional failure of such ash ponds not only affects vast tracts of agricultural land nearby but also pollutes river water even up to 100 KM endanger aquatic and human life. For proper operation of fly ash, physical, chemical and engineering categorization of fly ash is essential. Variability of material properties arising from different plants, same plant over period of time due to different coal supply (Winter and Clarke, 2002; Yudhbir and Honjo, 1991) and methods of operation of plant and variation in power generation (Lee et al., 1999) further necessitate the need for classification of fly ash from different sources. The fly ash is disposed of either in the dry form or mixed with water and release in slurry into locations called ash ponds. The quantity of fly ash produced wide-reaching is huge and keeps increasing every day. Four countries, namely, China, India, United State and Poland alone produce more than 270 million tons of fly ash each year. With the over view, geo-engineering properties of fly ash are calculated in the laboratory following all the Indian standards (IS).

2.1 FLY ASH: AN OVERVIEW

Fly ash is a fine, glass powder recovered from the gases of burning coal through the production of electricity. These micron-sized earth elements consist mainly of silica, alumina and iron. When mixed with lime and water the fly ash form a cementitious compound with property very similar to that of Portland cement. Because of this similarity, fly ash can be used to replace a portion of cement in the concrete, providing some discrete quality advantages. The concrete is denser resulting in a tighter, smoother surface with less bleeding. Fly Ash is also known as Coal Ash, Pulverized Flue Ash, and Pozzolona. Fly ash closely resembles volcanic ashes used in production of the earliest known hydraulic cements about 2,300 years ago. Those cements were made near the small Italian town of Pozzuoli - which later gave its name to the term "pozzolan". A pozzolan is a siliceous or aluminous material. Instead of volcanoes, today's fly ash - the mineral residue produced by burning coal is captured from the power plant's exhaust gases and collected for use. The difference between fly ash and Portland cement becomes apparent under a microscope. Fly ash particles are almost totally spherical in shape, allowing them to flow and blend freely in mixtures. That potential is one of the properties making fly ash a desirable admixture for concrete.

Fly ash particles those are collected in electrostatic precipitators are usually silt size (0.074 - 0.005 mm).

Making a more productive use of fly ash would have considerable environmental remuneration, tumbling air and water pollution. Increased use as a partial cement or lime replacement would also correspond to savings in energy since fly ash has been called a high-energy-based material (Hausmann, 1990). Fly ash utilization, in particular in concrete, has significant environmental benefits.

Fig 1. Fly Ash

2.2 CHEMICAL COMPOSITION AND CLASSIFICATION

Fly ash consist mainly of silicon dioxide (SiO_2), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp, pointed and hazardous; aluminium oxide (Al2O3) and iron oxide (Fe2O3). Fly ashes are in general highly heterogeneous, consisting of a concoction of glassy particles with various exacting crystalline phases such as quartz, mullite, and various iron oxides.

Fly ash also contain environmental toxins in major amounts, jointly with arsenic -43.4 ppm, barium -806 ppm, beryllium -5 ppm, boron -311 ppm, cadmium -3.4 ppm, chromium -136 ppm, chromium VI -90 ppm, cobalt -35.9 ppm, copper- 112 ppm, fluorine -29 ppm, lead 56 – ppm, manganese -250 ppm, nickel-77.6 ppm, selenium -7.7 ppm, strontium -775 ppm; thallium -9 ppm, vanadium -252 ppm, and zinc -178 ppm.

Two classes of fly ash are defined by ASTM C618: "**Class F fly** ash and **Class C** fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely subjective by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite)."

2.3 GEO-TECHNICAL PROPERTIES OF FLY ASH

PARAMETERS	RANGE
Specific Gravity	1.90 –2.55
Plasticity	Non plastic
Maximum dry density (gm/cc)	0.9 –1.6
Optimum moisture content (%)	38.0 –18.0
Cohesion (kN/m^2)	Negligible
Angle of internal friction (j)	30^0–40^0
Coefficient of consolidation C_v (cm^2/sec)	1.75×10^{-5}–2.01×10^{-3}
Compression index C_c	0.05–0.4
Permeability (cm/sec)	8×10^{-6}–7×10^{-4}
Coefficient of uniformity	3.1–10.7

2.4 SELF-HARDENED FLY ASH

The free lime content of fly ash contribute to self-hardening, fraction of lime, present as free lime in the form of calcium oxide or calcium hydroxide, controls self-hardening characteristics of fly ashes.

Age hardening can be best related with the amount of free lime present in the fly ash. The unconfined compressive strength of fly ashes as a function of free lime present in them. The self-hardening value of the fly ashes is determined by conducting **unconfined compressive strength** tests on compacted samples of the moistened ashes.

Yudhbir and Honjo (1991) have classified fly ashes into three classes based on self-hardening values:

(a) The self-hardening value increases rapidly for 28 days and reaches values close to 20 N/mm2

(b) Self-hardening values of 1–3 N/mm2 with 12–16 weeks with moderate increase in strength, and

(c) Very slow rate of increase in strength varying from 0.1 to 0.4 N/mm2.

2.5 USES OF FLY ASH

1. Portland cement.
2. Embankments and structural fill.
3. Waste stabilization and solidification.

4. Raw feed for cement clinkers.
5. Mine reclamation.
6. Stabilization of soft soils.
7. Road sub base.
8. Aggregate.
9. Flow able fill.
10. Mineral filler in asphaltic concrete.
11. Application on rivers to melt ice.
12. Used as a sub-base product in pavement design.
13. Other applications include cellular concrete, geo polymers, & roofing tiles.

3. EXPERIMENTAL SETUP& PROCEDURES

3.1 GRAIN SIZE ANALYSIS (BY HYDROMETER) [IS 2720(part-IV)-1985]

This process describes the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 71 um is determined by a sedimentation process, by means of a hydrometer to secure the essential data.

Dispersing agent - prepare a solution of sodium hexametaphosphate (sometimes called sodium metaphosphate) in distilled or demineralised water. 40 g of sodium hexametaphosphate/litre is used in the solution.

About 50 g of fly ash is taken and added with water and sodium hexametaphosphate and put in the mechanical stir cup. String process occurs for a period of 15 mins. After that it is poured into the hydrometer flask. After 20 s the Hydrometer is inserted gently to a depth slightly below its floating position.

Hydrometer readings are taken in the interval of 1/2, 1, 2, and 4 minutes. After that it was taken out and rinse with distilled water.

The hydrometer was re-inserted in the suspension and readings are taken after periods of 8, 15, and 30 minutes; 1, 2 and 4 hours after shaking. The hydrometer is removed and rinsed with water after each reading.

3.2 COMPACTION TEST (IS 2720(VII):1980)

3.2.1 STANDARD PROCTOR TEST

The standard proctor test was invented by **R.R.Proctor** (1933) for the construction of earth fill dams in the state of California. The standard proctor test apparatus consists of the following:

- Cylindrical metal mould, having an internal diameter of 10 cm, an internal effective height & volume of 12.5 cm, 1000 ml respectively.
- Removable base plate.
- Collar 5 cm in effective height.
- Rammer 2.5 kg in mass falling from a elevation of 30.5 cm.

The test consists in compacting soil at a range of water contents in the mould, in three equal layers, each layer being given 25 blows of the 2.5 kg rammer dropped from a height of 30.5 cm. The dry density obtain in each test is determined by knowing the mass of the compacted soil and its water content. The compactive energy used for this test is 6065 kg cm per 100 ml of soil. About 2.5 kg of oven dried soil passing through 4.75 mm sieve is then taken and thoroughly mixed with water. The amount of water to be added originally depends upon the probable optimum water content for the soil. The initial water content is taken about 4% for the used samples of fly ash. The empty mould attached with the base plate is weighted without collar. The collar is then attached to the mould. The mixed and matured soil is placed in the mould and compacted by giving 25 blows of the rammer homogeneously distributed over the surface, such that the compacted height of the soil is about 1/3 the height of the mould. The second and the third layers are similarly compacted, each layer being given 25 blows. The last layer should not project extra than 6 mm into the collar. The collar is separate and the top layer is trimmed off to make it level with the top of mould.

The bulk density and the corresponding dry density for the compacted soil are calculated from the following relations:

$$\rho = M/V \ \text{g/cc}$$

$$\rho_d = \rho / (1+W) \ \text{g/cc}$$

Where, ρ = Bulk density of soil (g/cc)

ρ_d = Dry density of soil (g/cc)

M=Wmass of wet compacted mould (g)

W= water content ratio ()

V= volume of the mould (1000 ml)

The test is repeated with increasing water contents, and the corresponding dry density obtained is therefore determined. A compaction curve is plotted between the water content as abscissa and the corresponding dry densities as ordinates. The dry density goes on increasing till the maximum density is reached. This density is called maximum dry density (MDD) and the corresponding moisture content is called optimum moisture content (OMC).

3.3 SPECIFIC GRAVITY TEST (BY DENSITY BOTTLE) [IS: 2720(part-III/sec-I) 1980]

The definition of specific gravity is the ratio of the weight in air of a given volume of a Material at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.

The purpose of the test is to determine the specific gravity of soil passing 4.75 mm sieve by density bottle method.

50 g of sample of fly ash is taken in each 3 bottles and added with water; weight of water + bottle is taken. Then all the 3 bottles are subjected to sand bath, heating is done up to air bubbles are seen in the bottle. This is done to remove the entrapped air in the mixture; the bottle is kept for around 1 hour so that the temperature comes to 27° C.

3.4 CBR ANALYSIS [IS 2720(XVI):1987]

This method describes the sampling of the sub grade for California Bearing Ratio (C.B.R.). The consequential information is used for pavement design thickness. **Remoulded Specimen**: Remoulded specimen are prepared at Proctors OMC and MDD.Then the specimen is prepared by dynamic compaction.Un-soaked CBR test was performed.

Dynamic compaction: about 2.95 kg of fly ash is taken, which is prepared with OMC and MDD of fly ash and compacted in a compression machine.

Penetration Test: The mould assembly with the surcharge weights was placed on the penetration test machine. The penetration piston was set at the centre of the specimen with the smallest possible load, but in not more than 4 kg so that full contact of the piston on the sample was established. The stress and strain dial gauge was set to read zero. Apply the load on the piston so that the penetration rate is about 1.25 mm/min.Load gauge readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, & 4.0 where recorded.

For penetration Test

Calibration factor of the proving ring	1 Div. = 1.1236 N
Surcharge weight used (kg)	2.950 kg
Least count of penetration dial	1 Div. = 0.002 mm

3.4.1 Standard loads used in a C.B.R. Test

Penetration of plunger(mm)	Standard load (kg)
2.5	1370
5.0	2055
7.5	2630
10.0	3180
12.5	3600

CBR = [TEST LOAD / STANDARD LOAD] * 100

3.5 DIECT SHEAR TEST (IS 2720(XIII):1986)

The purpose of this test was to calculate cohesion (C) and angle of friction (ϕ) of fly ash. As fly ash is non-cohesive at un-disturbed state, sample was made at its OMC.

Fly ash specimen was made at OMC, and then it is prepared by pushing a cutting ring of size of 10 cm in diameter and 2 cm high. The square specimen of size 6*6 cm is then cut from the circular specimen so obtained.

The lower part of shear box which bear against the load jack was set along the upper part of the box to bear against the proving ring.

Dial of the proving ring was set to zero. The normal stress at 25, 50, 75 (lb) was recorded.

3.6 PERMEABILITY TEST (CONSTANT HEAD) [IS 2720(XVII):1986]

The use of this test is to determine the permeability (hydraulic Conductivity) of fly ash by the constant head test method. Permeability (or hydraulic conductivity) refers to the ease with which water can flow through a soil. This property is essential for the calculation of seepage through earth dams or under sheet pile walls, the calculation of the seepage rate from waste storage facilities (landfills, ponds, etc.).

Calculate the permeability, using the following equation:

$K_T = QL / Ath$

Where, K_T = coefficient of permeability at temperature T, cm/sec.

L = length of specimen (cm)

t = time for discharge (seconds)

Q = volume of discharge (cm3, assume 1 ml = 1 cm3)

A = cross-sectional area of permeameter (D^2

, D= inside diameter of the permeameter)

h = hydraulic head difference across length L, in cm of water.

3.7 UN-CONFINED COMPRESSIVE TEST

[IS: 2720 part-(X):1991]

The primary purpose of this test is to determine the unconfined compressive strength, which is then used to calculate the unconsolidated undrained shear strength of the clay under unconfined conditions. According to the ASTM standard "the unconfined compressive strength (qu) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test". In addition, in this test method, the unconfined compressive strength is taken as the maximum load attained per unit area, or the load per unit area at 15% axial strain, whichever occurs first during the performance of a test

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The unconfined compression test is a particular case of triaxial compression test in which $\sigma 2=\sigma 3=0$. The cell pressure in the triaxial cell is also called the confining pressure. Due to the lack of such a confining pressure, the uniaxial test is called the unconfined compression test. The cylindrical specimen of soil is subjected to major principal stress $\sigma 1$ till the specimen fails due to shearing along a critical plane of failure.

In its simplest form, the apparatus consists of a small load frame fitted with a proving ring to calculate the vertical stress applied to the soil specimen. The deformation of the sample is calculated with the help of a separate dial gauge. The ends of the cylindrical specimen are hollowed in the form of cone. The cone seating reduce the tendency of the specimen to become barrel shaped by reducing end-restraints. During the test, load versus deformation readings are taken and a graph is plotted. When a brittle failure occurs, the proving ring dial indicates a exact maximum load which drops rapidly with the further increase of strain. For the duration of the test, load versus deformation readings are taken and a graph is plotted. When a brittle failure occurs, the proving ring dial indicate a definite maximum load which drops rapidly with the additional increase of strain. In the plastic failure, no definite maximum load is indicated. In such a case, the load corresponding to 20% strain is randomly taken as the failure load.

1. The stabilized samples were ready using constant mould of internal diameter 5cm and height 10cm by static compression method.
2. The unconfined compressive test was performed immediately and after 7 days.
3. Area of c.s=π(50)²/4=1963.49
4. LC of dial gauge=0.01 mm
5. Corrected area=A/(1-ε)

4. APPENDIX-I (LIST OF TABLES)

4.1 TABLE FOR GRAIN SIZE DISTRIBUTION OF FLY ASH BY HYDROMETER

SL NO.	ELAPSED TIME (t) MINS	HYDRO METER READING	MENISCUS CORRECTION (c)	CORRECTED READING	EFFECTIVE DEPTH(H_e)	FACTOR (F)	PAPRTIC LE SIZE	% FINER BASED ON M_d	% FINER (N) BASED ON HOLE
1	**0.5**	**21**	**0.5**	**21.5**	**11.6**	**1264**	**0.0723**	**76.4**	**19.35**
2	**1**	**20.5**	**0.5**	**21**	**11.9**	**1264**	**0.0654**	**75.8**	**19.08**
3	**2**	**20**	**0.5**	**20.5**	**12.2**	**1264**	**0.0532**	**74.1**	**17.20**
04	**4**	**19.5**	**0.5**	**20**	**12.4**	**1264**	**0.0426**	**73.2**	**17.16**
5	**8**	**18.5**	**0.5**	**19**	**12.6**	**1264**	**0.0413**	**72.8**	**17.02**
6	**16**	**18**	**0.5**	**18.5**	**12.8**	**1264**	**0.0216**	**69.4**	**15.4**
7	**30**	**17.5**	**0.5**	**18**	**12.9**	**1264**	**0.0207**	**67.5**	**15.01**
8	**45**	**16**	**0.5**	**16.5**	**12.9**	**1264**	**0.0112**	**66.1**	**14.25**

9	**60**	**15.50**	**0.5**	**16**	**13.1**	**1264**	**0.0084**	**58.5**	**13.8**
10	**240**	**14**	**0.5**	**14.5**	**13.2**	**1264**	**0.0076**	**52.6**	**13.2**
11	**300**	**13.50**	**0.5**	**14**	**13.4**	**1264**	**0.0069**	**48.3**	**12.4**
12	**1440**	**13**	**0.5**	**13.5**	**13.8**	**1264**	**0.0032**	**44.1**	**116**

4.2 STANDARD PROCTOR TEST OF FLY ASH

4.2.1.TABLE FOR DETERMINATION OF DRY DENSITY

Mass of mould + compacted soil(g)	5120	5400	5431	5528	5540	5527	5510
Mass of mould(g)	3986	3986	3986	3986	3986	3986	3986
Mass of compacted soil (g)	1134	1414	1445	1542	1554	1541	1524
Bulk Density (g/cm3)	1.13	1.41	1.44	1.54	1.55	1.54	1.52
Dry density (g/cm3)	0.99	1.21	1.22	1.29	1.27	1.25	1.225

4.2.2 TABLE FOR DETERMINATON OF MOISTURE CONTENT

Mass of container + wet soil (g)	108	109	115	117	59	88	72
Mass of container (g)	19.96	11.95	19.92	19.9	9.5	20.8	19.94
Mass of container + dry soil (g)	97	95	100	101	50	75	59

Mass of Water (g)	11	14	15	16	9	13	13
Mass of dry soil (g)	77.04	85.05	80.08	81.1	40.5	54.2	31.46
Water content (%)	14.27	16.46	18.73	19.72	22.2	23.98	24.2

4.3 TABLE FOR DETERMINATION OF SPECIFIC GRAVITY OF FLY ASH

	I	**II**	**III**	**IV**
Mass of bottle (M1)	107	88.34	96.46	117.1
Mass of bottle + fly ash(M2)	157	138.34	146.46	177.1
Mass of bottle+water+flyash(M3)	380.4	319	313.5	390.5
Mass of bottle + Water(M4)	355.7	287.05	295.5	365.9
Specific Gravity (G)	2.10	2.07	2.11	2.08

4.3 TABLE FOR DETERMINATION OF UN SOAKED CBR TEST OF FLY ASH

Dial gauge reading	Penetration (mm)	Proving ring Reading	Load(kg)	Corrected Load (kg)	CBR %
0	0	0	0		
50	0.5	95	21.38		
100	1	235	51.7		
150	1.5	445	98.0		
200	2.0	650	143		
250	2.5	860	189.3	189.3	13.8
300	3.0	960	211.4		

4.5 TABLE FOR DETERMINATION OF SHEAR PARAMETERS (C &ϕ) OF FLY ASH BY DIRECT SHEAR METHOD

sl no.	load	probing ring reading	shear force(lb)	normal stress(kg/cm²)	shear force(kg/cm²)
1	25	34	28.798	0.277777778	0.32912
2	50	42	35.574	0.555555556	0.40656
3	75	58	49.126	0.833333333	0.56144

4.6 TABLE FOR DETERMINATION OF PERMEABILITY OF FLY ASH BY CONSTANT HEAD METHOD

1.Hydraulic Depth (cm)	6
2.Length of the sample(cm)	6
3.Hydraulic Gradient	1
4.Cross sectional area of the sample(cm²)	50
5.Time interval (sec)	800
6.Quantity of flow(ml): I test	19
II test	16
III test	16
Average	17
7.Coefficient of permeability (cm/sec)	$4.2*10^{-4}$

4.7.1 TABLE FOR UCS OF FLY ASH (IMMEDIATE)

Dial gauge reading	Deformation(mm)	Proving ring reading	Load(KN)	Strain (ε)	Corrected Area(mm²)	Compressive strength(N/mm²)
0	0	0	0	0	1963.49	0
50	0.5	15	0.033708	0.005	1973.356784	0.017081554
100	1	28	0.0629216	0.01	1983.323232	0.031725338
150	1.5	45	0.101124	0.015	1993.390863	0.05072964
200	2	70	0.157304	0.02	2003.561224	0.0785122
250	2.5	95	0.213484	0.025	2013.835897	0.106008638
300	3	135	0.303372	0.03	2024.216495	0.149871321
350	3.5	158	0.3550576	0.035	2034.704663	0.174500804
400	4	152	0.3415744	0.04	2045.302083	0.167004377
450	4.5	140	0.314608	0.045	2056.010471	0.153018676
500	5	128	0.2876416	0.05	2066.831579	0.139170314

4.7.2 TABLE FOR UCS OF FLY ASH (AFTER 7 DAYS CURING)

Dial gauge reading	Deformation(mm)	Proving ring reading	Load(KN)	Strain(ε)	Corrected Area(mm²)	Compressive strength(N/mm²)
0	0	0	0	0	1963.49	0
50	0.5	32	0.0719104	0.005	1973.356784	0.036440648
100	1	56	0.1258432	0.01	1983.323232	0.063450676
150	1.5	98	0.2202256	0.015	1993.390863	0.110477882
200	2	130	0.292136	0.02	2003.561224	0.145808372
250	2.5	174	0.3910128	0.025	2013.835897	0.194163189
300	3	180	0.404496	0.03	2024.216495	0.199828428

350	3.5	162	0.3640464	0.035	2034.704663	0.178918546
400	4	148	0.3325856	0.04	2045.302083	0.162609525

5. APPENDIX II (FIGURES)

Fig-1: GRAIN SIZE DISTRIBUTION OF FLY ASH (HYDROMETER ANALYSIS)

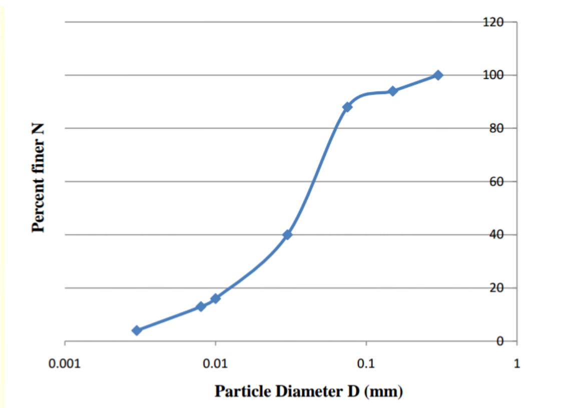


Fig-2: VARIATION OF DRY DENSITY W.R.T MOISTURE CONTENT IN STANDARD PROCTOR TEST

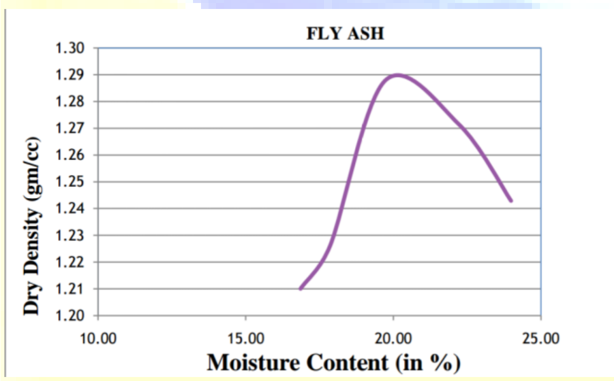


Fig-3: UN SOAKED CBR OF FLY ASH

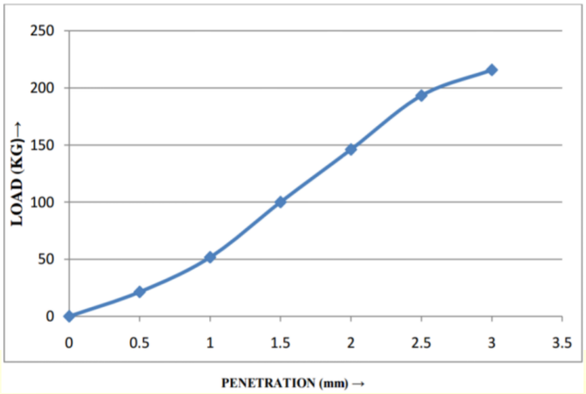


Fig-4: DIRECT SHEAR TEST

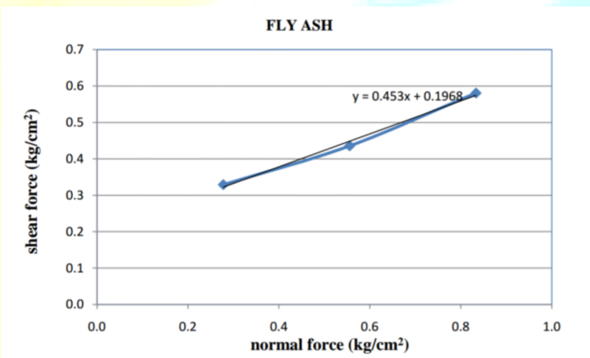


Fig-5.1: UCS TEST FOR FLY ASH (IMMEDIATE)

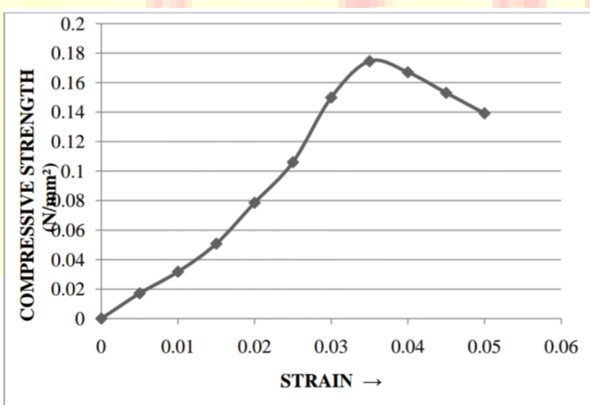
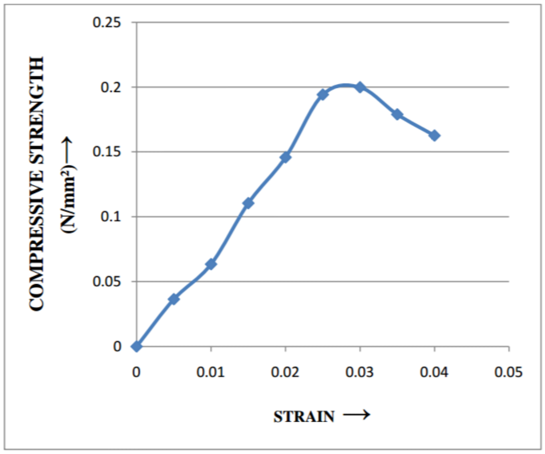


Fig5.2 UCS OF FLY ASH AFTER 7 DAYS CURING



6. RESULTS AND DISCUSSION

6.1 GRAIN SIZE DISTRIBUTION

1. The grain size analysis show that it contains particles mainly of silt size with no plasticity.
2. The percentage of clay and silt content is 87% and fine sand is 13%.
3. The coefficient of uniformity (C_u) was found out to be 3.08 and
4. The coefficient of curvature (C_c) was found out to be 1.02.
5. The grain size analysis indicates fly ash is uniformly graded.

6.2 From the **compaction test**, the MDD & OMC is found to be 1.29g/cc and 19.8 % respectively**.**

6.3 **Specific Gravity** of fly ash found to be 2.09

6.4 The **CBR** of fly ash 13.8% in un-soaked condition.

6.5 The shear parameter **C & ɸ** are found to be 0.1968 kg/cm², 24.37° respectively, when sample is prepared at OMC.

6.6 The **permeability** of fly ash under dynamic compaction comes to be $4.2*10^{-4}$ cm/sec.

6.7 **UCS** of immediate sample was 0.174 N/mm² and after 7 days curing it is 0.199 N/mm².The UCS of stabilized samples increases with increase in the days of curing.

7. CONCLUSION

1. Fly ash contains mostly clay and silt particles and the gradation of particles are uniform.
2. The specific gravity of fly ash is 2.09; which is lighter than conventional earth material. This is advantageous in constructing light weight embankments over soft compressible soil.

3. The un-soaked CBR value of fly ash, compacted to its MDD at OMC is 13.8%. IRC: 37-2001 states that CBR value for sub base should be 20% up to 2 msa and should not be less than 30% after 2 msa. Hence, this fly ash is not suitable for sub bases in either of these conditions.
4. The permeability of fly ash under dynamic compaction comes to be $4.2*10^{-4}$ cm/sec, which is very high and cannot be used as a direct material in pavement, earth dam etc.
5. UCS of immediate sample was 0.174 N/mm² and after 7 days curing it is 0.199 N/mm². The unconfined compressive strength of stabilized samples increases with increase in the days of curing.

8. IMPORTANT INDIAN STANDARD SPECIFICATION

1. **Methods of test for soil :** Determination of grain size analysis

   IS 2720(IV):1985

2. **Methods of test for soil:** Determination of compaction properties

   IS 2720(VII):1980

3. **Methods of test for soil:** Determination of specific gravity

   IS 2720(III/SEC-I): 1980

4. **Methods of test for soil:** Determination of CBR

   IS 2720(XVI):1987

5. **Methods of test for soil:** Determination of direct shear test

   IS 2720(XIII):1986

6. **Methods of test for soil:** Determination of permeability

   IS 2720(XVII):1986

7. **Methods of test for soil:** Determination of un- confined compression test.

   IS 2720(X):1991

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