SOIL STABILIZATION USING FLY ASH

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Certificate

This to certify that the work entitled **"Soil Stabilization using Fly Ash"** submitted by**"Mohit Ahuja,Siddhant Chaudhary,Aakash Pathak,& Nitish Sachdeva"**in partial fulfillment for the award of degree of Bachelor of Technology in Civil Engineering of Jaypee University of Information Technology has been carried out under my supervision. This work has not been submitted partially or wholly to any other University.or institute for the award of this or any other degree or diploma

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ABSTRACT

Soil stabilization has become the major issue in construction engineering and the researches regarding the effectiveness of using industrial wastes as a stabilizer are rapidly increasing.

The basic objective of the project was to, study the engineering properties of soils of Waknaghat and, then study how its engineering properties could be improved through the use of Fly ash as an additive also being economical for use on large scale.

For the above purpose, soil samples from the hills around JUIT Waknaghat campus, were excavated and several civil engineering laboratory tests were conducted to study the geotechnical properties of Fly ash and strength gain when mixed with local soil sample. A different proportion of Fly ash and soil sample cured for 7 days results in a strength gain. A better understanding of the properties of Fly ash is gained from the study and the tests indicate an improved strength and better properties of soil sample when stabilized.

Fly ash for its application as an additive, was procured from Jaypee Cement Plant at Baga, district Solan ,Himachal Pradesh, and thereafter extensive tests were conducted to study the variation in engineering properties of soil with varying amount of Fly ash.

As was expected, various engineering properties of soil displayed much higher values before failure in contrast to the original values, obtained without using Fly ash, thereby giving a measure of effectiveness of Fly ash as a reliable admixture for the purpose of soil stabilization.

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LIST OF SYMBOLS

C_u: Coefficient of uniformity

C_c: Coefficient of curvature

D_{10}: Effective diameter

W_L: Liquid limit

W_P: Plastic limit

PI: Plasticity Index

σ: Shear Stress

τ: Normal Stress

Φ: Angle of internal friction

G: Specific gravity of soil

e: Void ratio of soil

Y_w: Density of water

O.M.C: Optimum moisture content

$Y_{d\,max}$: Maximum dry density

Y_t: Bulk density

C_c: Compression index

C_V: Coefficient of consolidation

T_v: Time factor, depending on degree of consolidation

w: Moisture content

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1. Introduction

1.1 Background

Soil Stabilizationis improving the engineering properties of soils used for pavement base courses, sub-base courses, and sub-grades by the use of additives which are mixed into the soil to effect the desired improvement.

Civil engineering projects located in areas with soft or weak soils have traditionally incorporated improvement of soilproperties by using cement and lime. Use of Fly ash as a ground improvement soil admixture, when found viable,will be effective in terms of cost and a good approach to the environment to preserve and minimize accumulation ofindustrial waste.

This study is performed to obtain geotechnical properties of Fly ash for its application in the stabilization of soil. The geotechnical properties of Fly ash will be evaluated with various laboratory tests to investigatethe feasibility of using Fly ash in soft soil stabilization. Constructions over soft soil are one of the most frequent problems inmany parts of the world. The typical approach to soil stabilization is to remove the soft soil, and substitute it with a strongermaterial of crushed rock.

Successful modern soil stabilization techniques are necessary to assure adequate sub grade stability, especially for weaker or wetter soils. It is widely recognised that the selection between the cementitious stabilizing agents cement and lime is based on the Plasticity index of the primary soil type being improved. A PI of 10 is considered by many as the threshold that justifies the cost of use of Portland cement compared with lime. The use of bituminous agents is somewhat less common, but worthy of consideration. Working with bituminous emulsions requires close attention to application rate.

Fly ash was first used in large scale n the construction of Hungry Horse dam in America in the approximate amount of 30% by weight of cement later on it was used in canyon and ferry dams etc. In India Fly ash was used in Rihand dam construction replacing cement up to 15%.

Fly ash is one of the most plentiful and industrial by-products. It is generated in vast quantities as a by-product of burningcoal at electric power plants. Electric utility companies in many parts of the world generate electricity byburning coal which generate an amount of fly and bottom ash. Fly ash generated by coal combustion based power plantstypically fall within the ASTM Fly ash classes C and F. Fly ash consists of inorganic matter presentin the coal that has been fused during coal combustion. This material is solidified while suspended in the exhaust gases andis collected from the exhaust gases by electrostatic precipitators. Since the particles solidify while suspended in the exhaustgases, Fly ash particles are generally spherical in shape. Fly ash particles those are collected inelectrostatic precipitators are usually siltsize (0.074 - 0.005 mm). Making a more productive use of Fly ash would haveconsiderable environmental benefits, reducing air and water pollution. Increased use as a partial cement or lime replacementwould also represent savings in energy because Fly ash has been called a high-energy-based material.

1.2Types of Stabilizers

1.Chemical

1. Fly ash
2. Lime
3. Portland Cement
4. Lime Cement
5. Geosynthetics

2. Geosynthetics

1.2.1 Stabilization by Chemicals

1.2.1.1 Stabilization withFly ash

Class C Fly ash is an industrial byproduct generated at coal fired electricity generating power plants that contains silica, alumina and calcium based minerals.

Upon exposure to water, these calcium compounds hydrate and produce cementitious products similar to the products formed during the hydration of Portland cement.

The rate of hydration for Fly ash is much more rapid than Portland cement. It is therefore more desirable to mix and compact Fly ash as quickly as practical.

The hydration property depends on coal source, boiler design and the type of ash collection system. The coal source governs the amount and type of organic matter present in it.

Eastern coal source contain small amount of calcium. This class F Fly ash does not exhibit self-cementing characteristics.

Western coals contain higher amount of calcium (about 20%-35%) and are classified as class C Fly ash.

$CaO + H_20 \rightarrow Ca(OH)_2$

$Ca(OH)_2 \rightarrow Ca^{++} + 2[OH]^-$

$Ca^{++} + 2[OH]^- + SiO_2 \rightarrow CSH$

(Silica) (Gel)

$Ca^{++} + 2[OH]^- + Al_2O_3 \rightarrow CAH$ (alumina) (gel)

*1.2.1.2 **Stabilization with Lime***

Lime stabilization is done by adding lime to soil. This is useful for the stabilization of clayey soil. When lime reacts with soil there is exchange of cations in the adsorbed water layer and a decrease in the plasticity of the soil occurs. The resultant material is more friable than the original clay, and is more suitable as subgrade. Lime is produced by burning of limestone in kiln. The quality of lime obtained depends on the parent material and the production process. And there are basically 5 types of limes:

High calcium, quick lime (CaO)

Hydrated high calcium lime [$Ca(OH)_2$]

Dolomitic lime [CaO+MgO]

Normal, hydrated Dolomitic lime [$Ca(OH)_2$+MgO]

Pressure, hydrated Dolomitic lime [$Ca(OH)_2$+MgO2]

The two primary types of lime used in construction today are quick lime (calcium oxide) and hydrated lime (calcium hydroxide).Heating limestone at elevated temperatures produce quick lime and addition of water to quick lime produces hydrated lime. Equation shows the reaction that occurs when limestone is heated to produce quick lime with carbon dioxide produced as by-product.

$CaCO3 + heat \rightarrow CaO + CO2$

Addition of water to quick lime produces hydrated lime along with heat as by product:

$CaO + H2O \rightarrow Ca\ (OH) + Heat$

For stabilization with lime, Soil conditions and mineral logical properties have a significant effect on the long term strength gain.

1.2.1.3Stabilization with Portland cement

Portland cement can be used either to modify or improve the quality of the soil into a cemented mass with increased strength and durability.

The amount of cement used will depend upon whether the soil is to be modified or stabilized.

Cement stabilization is most commonly used for stabilizing silt, sandy soils with small quantities of silt or clayey fractions stabilization of soil with cement has been extensively used in road construction.

Mixing the pulverized soil and compact the mix to attain a strong material does this stabilization. The material thus obtained by mixing soil and cement is known as 'soil cement'.

The soil content becomes a hard and durable structural material as the cement hydrates and develops strength.

The cementing action is believed to be the result of chemical reaction of cement with the siliceous soil during hydration.

1.2.1.4Lime-cement

Lime can be used as an initial additive with Portland cement or the primary stabilizer.

The main purpose of lime is to improve workability characteristics mainly by reducing the plasticity of soil. The design approach is to add enough lime to improve workability and to reduce the plasticity index to acceptable levels. The design lime content is the minimum that achieves desired results

1.2.2Stabilization by Geosynthetics

Introducing geo-textiles and fabrics that are made of synthetic materials, such as polyethylene, polyester, and nylon, can stabilize the soil.

The geo-textile sheets are manufactured in different thickness ranging from 10 to 300 mils (1mil=0.254mm).

The width of sheet can be up to 10m. These are available in rolls of length up to about 600m.

Geotextiles are permeable. Their permeability is compared to that of fine sand to course sand and they are strong and durable.

1.2.2.1 Types of Geosynthetics

The 4 basic polymers used as crude materials for geotextiles are:

Polyester

Polyamide

Polypropylene

Polyethylene

Geotextiles can be either of the following categories

Woven Geotextiles: These geotextiles were the first to be developed from the synthetic fibres using weaving techniques adapted from those used to weave clothing textiles.

Non woven Geotextiles: These were the second type of geotextiles to be invented and were named so to distinguish them from the woven geotextiles.

Knitted geotextiles: As the name suggests they are manufactured by interlocking a series of loops of yarn together.

1.3Objective of the present study

In the present scenarioFly ash has become an essential ingredient of concrete and is extensively used in the production of high strength and high performance concrete

The use of Fly ash as concrete admixture is not only technically advantageous to the properties of concrete but also contributes to the environmental pollution control .In India alone 75 million tons of Fly ash per year the disposal of which has become a serious environmental problem, hence it's effective application in concrete production and in the field of soil stabilizations only helps in decreasing the pollution and contributing to the cause of environment.

Secondly, cement is the back bone for global construction industry, but production of every ton of cement carbon dioxide to the tune of 0.87 ton .Expressed in another way it is the cause of nearly 7% carbon dioxide emission in the world, because of it's significant contribution to environmental pollution and to the high consumption of natural resources like limestone ,etc there arises a need to economize cement .One of the practical solutions to economize cement is to replace cement with supplementary cementitious materials like Fly ash and Slag.

In India the total production of Fly ash is nearly 75 million ,but utilization of Fly ash is only about 5%,hence there is a an urgent need to popularize it's various applications in construction and soil stabilizations practices .

In contrast to other techniques of chemical soil stabilization like stabilization through cement, bitumen, and lime stabilizations through Fly ash is the most cheapest techniques of soil stabilization and thereby contributes to the cause of environment as well.

Keeping in mind the above points it was decided in the present study to use Fly ash as a soil stabilizer. The main objective of the present study is therefore to stabilize the soil of Waknaghat nearby area using Fly ash.

2. Literature Review

Soil Stabilization is used to enhance the geotechnical properties of the soil. Various approaches may be used to achieve this objectives, however chemical approaches is widely used. Some work on use of geosyntenthic in soil stabilization has also been reported.

A few studies have however been carried out on the topic of stabilization of black cotton soil using fly ash. The present work is focused on the stabilization of sandy-silt soil using Fly ash. A brief description on all the topics are presented in the following section.

2.1 Stabilization of soil using Flyash

Low Cost Fly ash-Stabilized Sand, Des Moines County, Iowa (1984)

The main objective of this Iowa Department of Transportation project had been to develop a low cost Fly ash-stabilized roadway using locally available unprocessed sand. The project is located on county road H-40 in Des Moines County. The roadway is adjacent to the Mississippi River levee and traffic was estimated at 27,000 ESALs. The mixture for the project consisted of 5.1% Type I cement, 13.7% Ottumwa Class C Fly ash (23% CaO), sand, and water. The grade was prepared in July 1984. Construction of the base course began on August 1, 1984 and was completed on August 4, 1984.
The mixture was mixed off-site in a central plant mixer, then transported to the site in dump trucks and placed in front of a subgrade trimmer. Compaction of the mix was difficult at times due to the material shoving under the roller. The average density was 97.6% of standard Proctor and strength testing was conducted by coring the base at 14, 28, 91, and 313 days. Strengths were greater than typical lime-Fly ash mixtures. However, the main objective, a low cost, was not met. After the road had been through two years of heavy tractor-trailer traffic, it was noted that an overlay would be necessary.

Northwest Highway Fly ash Stabilization, Oklahoma (1994)

The material on this site was sandy clay and required stabilization. The design engineers specified an ash addition rate of 15%, which was initially to be mixed to a depth of eight inches with the existing sub-base. After preliminary mixing, water was sprinkled on the mixture and a second pass of the mixing equipment immediately followed. The compaction window on the project was four to six hours. The stabilized subgrade was finished of with a ten-inch hot-mix asphalt layer.

Fly ash Stabilization of City Streets, Overland Park, Kansas (2002)

The city of Overland Park, Kansas required Fly ash stabilization for soils with a liquid limit greater than 40 and a plasticity index over 25. Stabilization work began in 1993 and became mandatory in 1996. During the late spring of 2002, field testing using the DCP was completed on 12 existing stabilized subgrades in Overland Park, with the oldest being 9 years. Overall, the test results on the stabilized subgrades show final CBR strength values between 140% and 350% of the original strength, as measured by the unstabilized underlying soils. No correlation existed between the CBR values and the age of the subgrade. Observations of the streets were made during testing, and it was noted that the streets are in good condition.

Self-Cementing Fly Ash Stabilization for an Industrial Road, Missouri (1992)

The project, completed in 1973, was located in Kansas City, Missouri and involved an industrial road underlain by clay soils with a liquid limit of 65, plasticity index of 43, and a low CBR value of 3.5. The initial pavement design included 12 inches of full-depth asphalt. However, reducing the pavement thickness by improving the subgrade was desired. Laboratory testing using a fly ash content of 15% from Hawthorne Power Station showed decreases in the liquid limit and plasticity index to 45 and 18, respectively. The 28 day unconfined compressive strength of the stabilized clay soil was seven times that of the native soil. Mixing took place on grade, in two 4.5-inch layers. Field CBR values increased to 9% unsoaked and 12.5% soaked. The increase in CBR allowed pavement thickness to be reduced to 9 inches, and as of 1975 the pavement was holding up to light traffic loads (GAI Consultants 1992).

Recycled Pavement, Shawnee County, Kansas

This 1.5-mile section of 93rd Street is considered a rural road but carries a high volume of truck traffic. The existing thickness of the road material varied from one to six inches for the asphalt surface and one to eight inches for the granular base over a clay subgrade. The mix design intended for 18% class C fly ash to be added to the pulverized pavement and base materials at a moisture content of 10%. Starting in June 1987, the pavement and base were pulverized to a six-inch depth and lightly compacted. The fly ash was spread on the surface and mixed with a Bomag MPH 100; water was added through nozzles in the mixing drum. Initial mixing was completed with a vibratory padfoot roller and final compaction was completed with a smooth drum or pneumatic rubber-tired roller. The stabilized section was kept moist for five days before a layer of cold-mix asphalt was placed. Two months after the asphalt was placed a chip seal surface was applied. The road was in excellent shape after four years of service (GAI Consultants 1992).

By S. Bhuvaneshwari ,R.G .Robinson and R.S. Gandhi

In their paper they have mentioned how Fly ash was successfully used in improving the properties of the expansive soils ,and how a trial embankment of 30 meter long,0.6 meter high and 6 meter wide was successfully constructed on expansive soils after its treatment with Fly ash ,and thereafter how the in-situ test performed ,proved the suitability of Fly ash for filling of low laying areas ,construction of ash dykes etc.

Concluding Remarks:

A few works is reported on topic of stabilization of expansive soil. But a little or no work has been carried out on stabilization of the sandy-slit soil using Fly ash. Therefore main objective of the present work was to carry out controlled sets of experimental investigation on sandy-silt soil to find out its engineering properties and stabilize the soil using chemical approach specially using Fly ash.

3. Experimental Program

Main objective of the present investigation was to stabilize the sandy-silt soil using chemical approach and to analyze the changes in the engineering properties of soil. Various additives are used in the chemical approaches such as Fly ash, lime, cement, and combination of lime-cement. Out of these use of fly ash is economical and hence in the present investigation Flyash is used as additive.

In order to achieve the following objectives, the experiments were conducted in two series. First series of experiments were carried out to know the properties of the natural soil (sandy-silt soil). In the second series of the experiments, soil was mixed with varying proportion of the Fly ash and different experiments were carried out to get the variation in various index properties.

3.1 Collection of samples

The samples of the soil were collected from isolated hills of Waknaghat nearby area, and in the vicinity of JUIT campus. It was ensured that they were free from all the debris due to the nearby constructions taking place.During the excavation process, a lot of sedimentary rocks were encountered with their size ranging from few centimeters to as long as 20 to 25 centimeters.Due to the presence of sedimentary rocks, the soil could be excavated to a depth of around, 20 centimeters, at a depth greater than 20 centimeters large deposits of sedimentary rocks were encountered, which made the excavation ahead impossible, without advanced excavation equipments. Therefore soil samples were collected from the top surface of the ground not exceeding depth equal to 20 cm.

It was also observed, that soil possessed very little cohesion and moisture thereby, rendering the soil to be in a very loose state. Hence soil is treated as sandy-silt soil with a small percentage of gravel.

First series of experiments

3.2 Tests performed on the soil

3.2.1 Sieve Analysis

3.2.2 Liquid and Plastic Limit

3.2.3 Moisture Content

3.2.4 Compaction Test

3.2.5 Specific Gravity

3.2.6 Bulk Density

3.2.7 Direct Shear Test

3.2.8 Consolidation Test

3.2.1 Sieve analysis

The size distribution is often of critical importance to the way the material performs in use.

A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal, soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method.

Being such a simple technique of particle sizing, it is probably the most common.

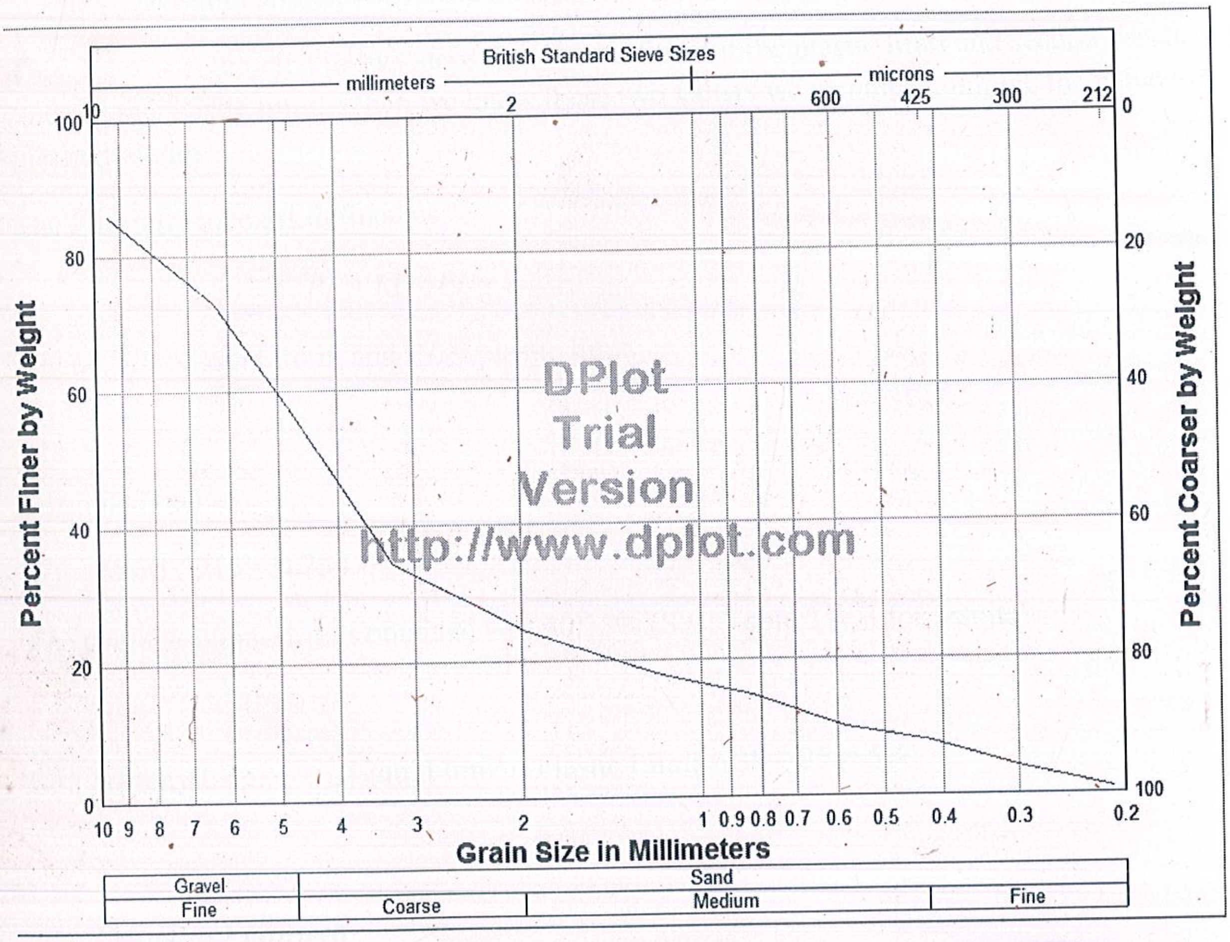

Figure 1: Grain size Distribution Curve

As per the graph it can be seen that the soil is fairly well graded.

The effective diameter of the soil grains D10 is o.15mm.

Cu, Coefficient of Uniformity as per the graph comes out to be 3.9.

Cc, Coefficient of Curvature comes out to be 1.07.

3.2.2Liquid limit and plastic limit

This testing method is used as an integral part of several engineering classifications systems to characterize the fine-grained fractions of soils and to specify the fine-grained fraction of construction materials.

The liquid limit, plastic limit and plasticity index of soils are also used extensively, either individually or together, with other soil properties to correlate with engineering behaviour such as compressibility, permeability, compactibility, shrink - swell and shear strength.

This test method covers the determination of the liquid limit, plastic limit and plasticity index of soils. The liquid and plastic limits of soils are often referred the as the Atterberg limits.

This test was conducted in two steps first was to find out the plastic limit and second was to find out the plastic limit. When we know these two values we can then compute the value of plasticity index.

The Plasticity index is defined as:

$$PI = LL - PL$$

where: LL = liquid limit, and PL = plastic limit.

Formula Used:-

$W_L = W_N/1.3215 - 0.23 \text{ Log } N$

The average Liquid Limit obtained was 30.33%.(See: Table 2 & 3 for results)

So Plasticity Index = Liquid limit – Plastic Limit = 30 – 25 = 5%

3.2.3Moisture content

This test is performed to determine the water (moisture) content of soils. The water content is the ratio, expressed as a percentage, of the mass of "pore" or "free" water in a given mass of soil to the mass of the dry soil solids.

The moisture Content found out after performing the test was calculated to be 0.80%.

3.2.4 Compaction Test

The purpose of the standard Proctor compaction test is to determine the optimum water content and the maximum dry density that can be achieved with a certain compaction effort.

The relationship between the moisture content and the density of the soil will be obtained in the process.

Compaction effort designed in this laboratory test is comparable with that obtained in the field.Compaction is the process of increasing the bulk density of the soil or aggregate by driving out the air. For a given soil, for a given amount of compaction effort, the density obtained depends on the moisture content.

Fig. 1 shows the plot between moisture content and dry density.

On the basis of the above plotted graph, optimum moisture content came out to be 22%.

Corresponding maximum dry density, $\gamma_{d\,max}$=1.64gm/cm^3.

3.2 .5 Specific Gravity

The specific gravity of soil is an important weight-volume property that is helpful in classifying soils and in finding other weight-volume properties like void ratio, porosity, and unit weight.

Temperature Correction Factor to obtain the specific gravity value at standard temperature of 27°C is 0.9998.

Specific gravity of the sample (temp=27°C) = 2.17

Since the G value is 2.17, therefore it can be interpreted, that the soil is in a medium loosestate as pointed out by relative density as well.

Relative density (I_d) is the term used to represent the degree of compaction of cohesion less soils.

I_d for the given soil came out be 50.70% thereby, indicating the soil to be medium dense

3.2.6 Bulk Density

Bulk density can be calculated by either core cutter method or sand replacement method.

Initially it was tried to obtain by less tedious core cutter method.

But as observed the soil possessed very little cohesion and moisture content therefore making it virtually impossible to obtain any sample in the core cutter.

Core cutter method was made further difficult due to presence of stones and rocks encountered at very shallow depth.

Bulk Density Result

Bulk density (γ_t)= 1.44gm/cm^3

The moisture content of soil was 0.8%

On the basis of the obtained moisture content the dry density came out to be 14.35 KN/m^3.

Void ratio, e = ($G\gamma_w$ /γ_d) -1=0.49.

3.2.7*Direct Shear Test*

The direct shear test is one of the oldest strength tests for soils. In this laboratory, a direct shear device is used to determine the shear strength of cohesion less soil (i.e. angle of internal friction).

This test is governed by the formula : $\tau = \sigma + \tan\varphi$

Since the soil possesses no cohesion or moisture as per the field observation.Therefore only parameter to be found (φ), angle of internal frictionThereby, out of tri axial test or direct shear test, direct shear test was performed.

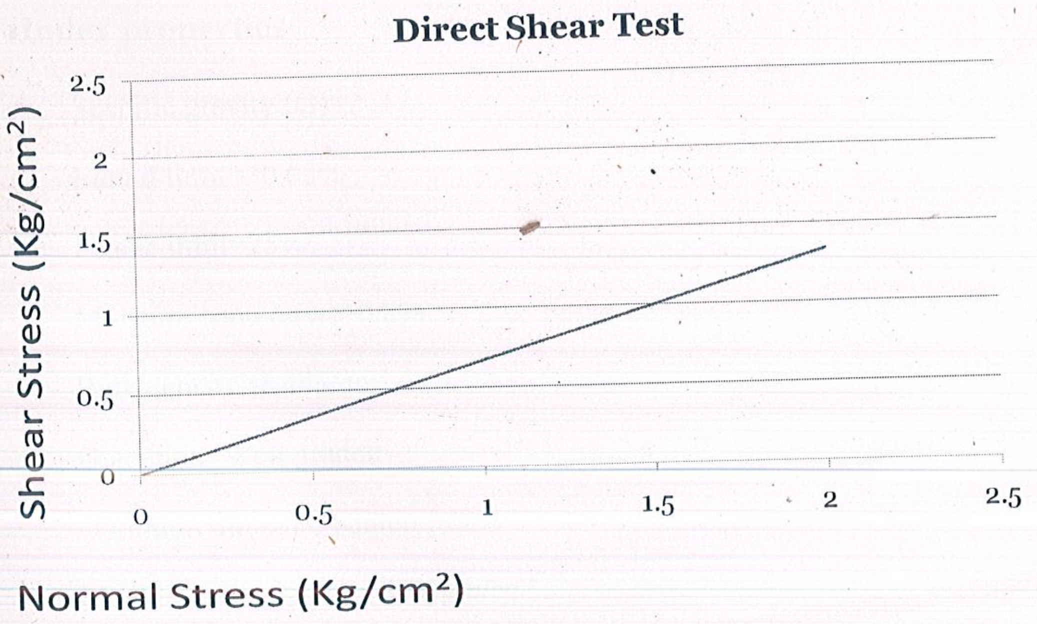

Figure 2: Angle of Internal Friction

As per the graph it can be concluded that the angle of internal friction is 33.7^o

3.1.8Consolidation Test

On the basis ofH_s,e, void ratio was calculated. The compression index C_c comes out to be 0.0996

Coefficient of consolidation $C_v = (T_v)_{90} d^2 / t_{90}$

$= 7.49*10^{-4}$ cm^2/sec

For Load increment of 95 KN/m^2

The coefficient of consolidation $C_V$could not be calculated due to nearly repetitive dial gauge readings under different loads

3.3Soil type – Conclusion

Soil can be identified as sandy silt(SM) with very little moisture content.

On the basis of above mentioned test conducted, it can be concluded that the tested soil is a fairly loose soil with hardly any moisture content and no cohesion.

Since the moisture content is negligible. Hence liquefaction is very unlikely to take place.

3.4Index properties

Specific gravity (G)=2 .17

Liquid limit=30.03%

Plastic limit=25%

Moisture content(w)=0.8%

Bulk density=1.44g/cm^3

Gradation: Well graded

Optimum moisture content: 22%

Maximum dry density: 1.64gm/cc

4. Analysis of Data and Discussion

Second series of experiments

Properties of Fly ash used

Class: F

Specific Gravity: 1.90-2.55

Plasticity: Non plastic

Maximum dry density (gm/cc):0.90-1.60

Optimum moisture content (%):18-38

Angle of internal friction: 30^0-40^0

Cohesion: Negligible (kg/cm^2)

Compression index: 0.05-0.4

Coefficient of uniformity:3.1-10.7

Particle size distribution

.Clay size fraction (%): 1-10

.Silt size fraction (%): 8-85

Sand size fraction (%):7-90

Gravel size fraction (%):0-10

4.1 Test performed with Fly ash as an additive

4.1.1 Specific Gravity test

4.1.2 Plastic Limit and Liquid Limit

4.1.3 Direct Shear test

4.1.4 Compaction test

4.1.5 Consolidation test

4.1.6 Bulk Density test

4.1.1Specific Gravity Test Performed with Fly ash

A comparative study of variation of Specific Gravity with varying content of Fly ash

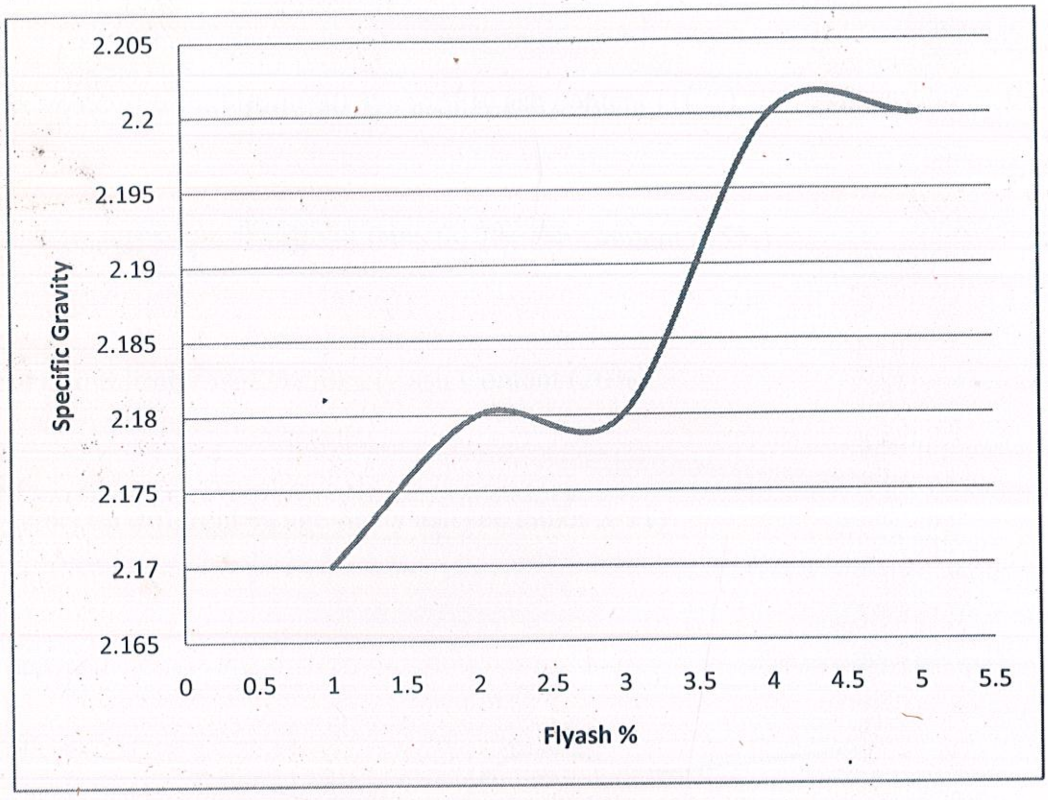

Figure3 : Specific Gravity Variationwith varying Fly ash content

For readings refer Table no. 7

Graphical representation of variation of Specific Gravity with varying Fly ash content

4.1.2Liquid Limit Test With Fly ash

Average value of liquid limit=30.405% for Fly ash content (5%)

Average value of liquid limit=30.3% for Fly ash content (10%)

Average value of Liquid limit=33.04% for Fly ash Content (15%)

Average liquid limit=34.42% for Fly ash Content (20%)

(For results on different % age of fly ash see tables 8-11)

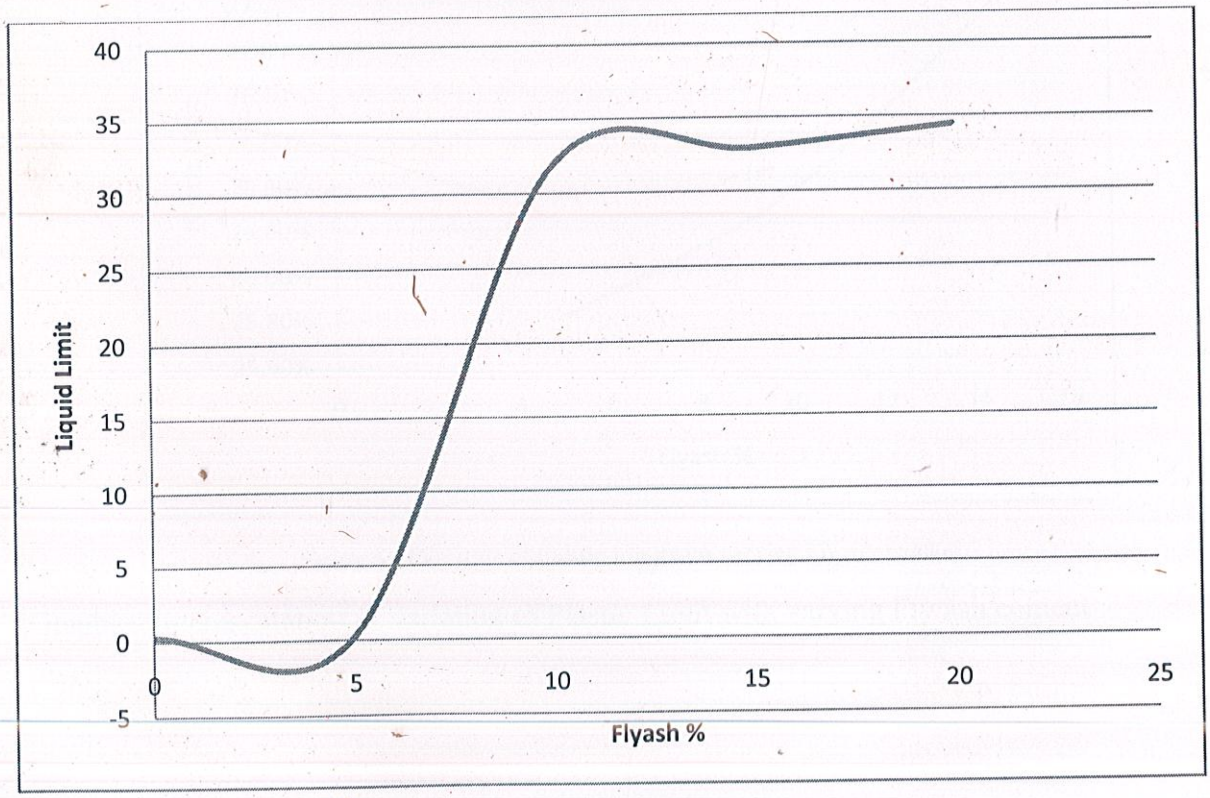

Figure 4 : Liquid Limit Variationwith varying Fly ash content.

Graphical representation of variation of Liquid limit with varying Fly ash content

4.1.3Plastic Limit Test With Fly ash

Average value of plastic limit=25.81% for Fly ash Content (5%)

Average value of plastic limit=26.35% for Fly ash Content (10%)

Average value of Plastic limit=27.28% for Fly ash Content (15%)

(see tables 12-14 for results on different % of fly ash)

Determining the plastic limit for 20%Fly ash concentration was not possible, since soil was crumbling before it could be rolled into 3mm threads

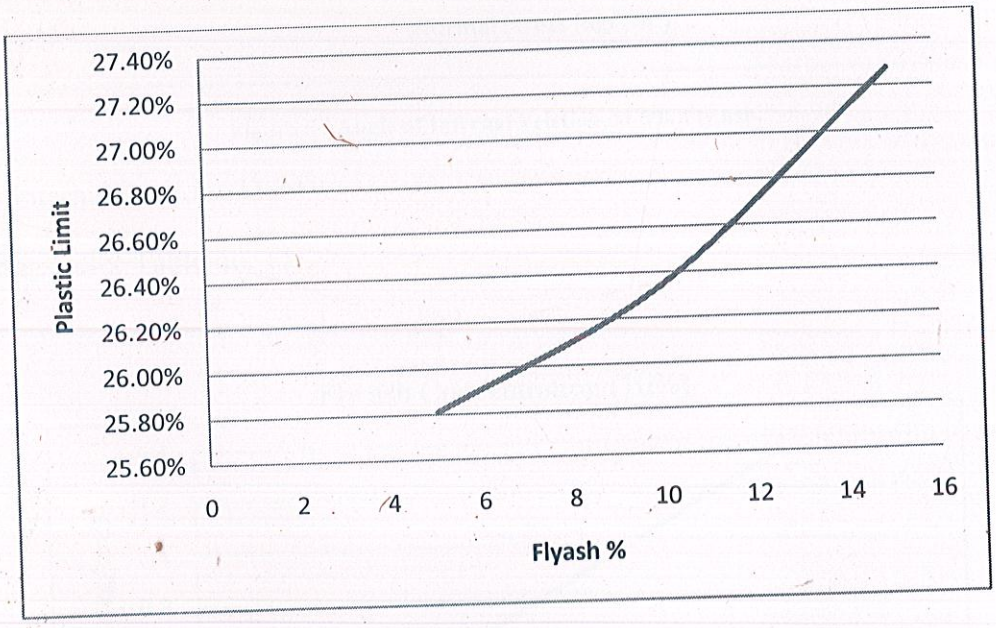

Figure 5 : Variation of Plastic Limitwith varying Fly ash content.

Graphical representation of variation of Plastic Limit with varying Fly ash content

4.1.4 Direct Shear test with Fly ash

Fly ash Concentration (5%)

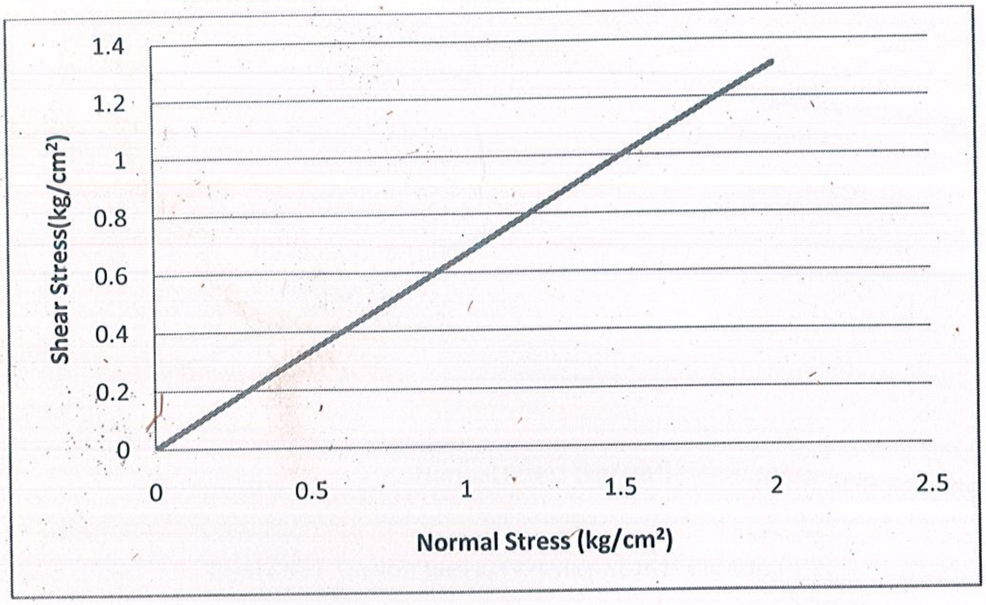

Figure 6 : Angle of Internal Friction At 5% Fly ash.

Angle of internal friction=33.34^0

For readings refer Table no. 15

Fly ash Concentration (10%)

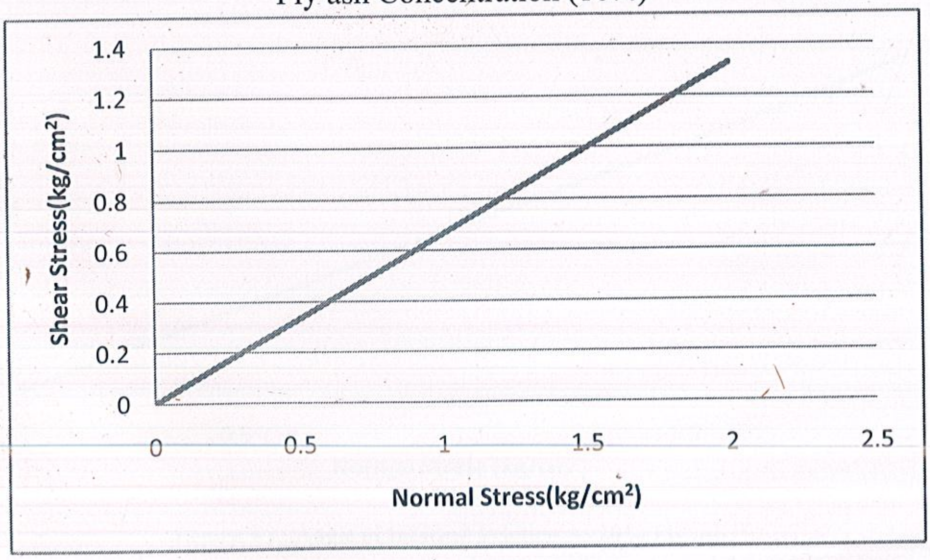

Figure 7 : Angle of Internal Friction At 10% Fly ash.

Angle of internal friction =33.50^0

For readings refer Table no. 16

Fly ash concentration (15%)

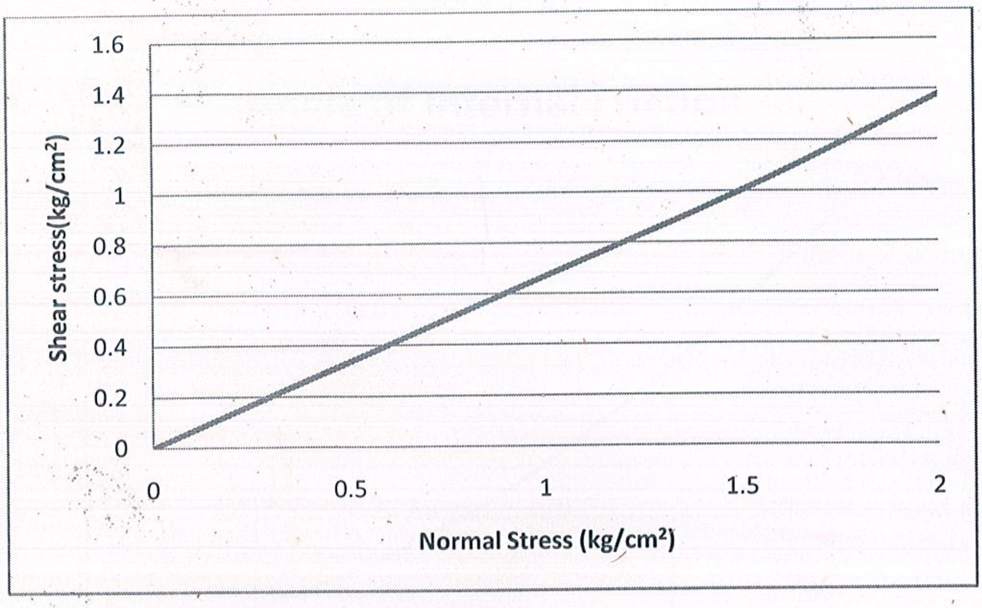

Figure 8 : : Angle of Internal Friction At 15% Fly ash.

Angle of internal friction=33.76^0

For readings refer Table no. 17

Fly ash concentration (20%)

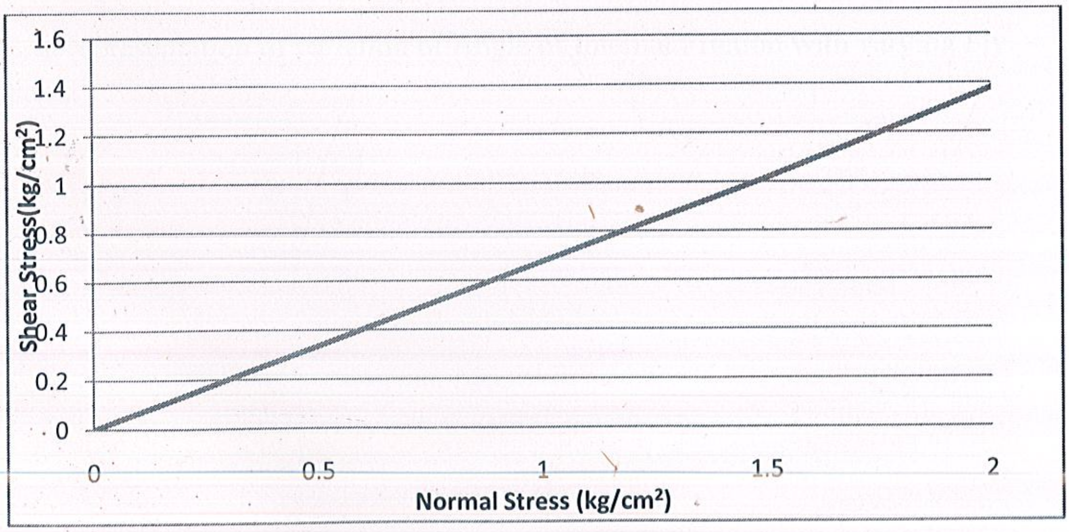

Figure 9 : : Angle of Internal Friction At 20% Fly ash.

Angle of internal Friction=34.1^0

For readings refer Table no. 18

A comparative study of variation of angle of internal friction with varying percentage of Fly ash

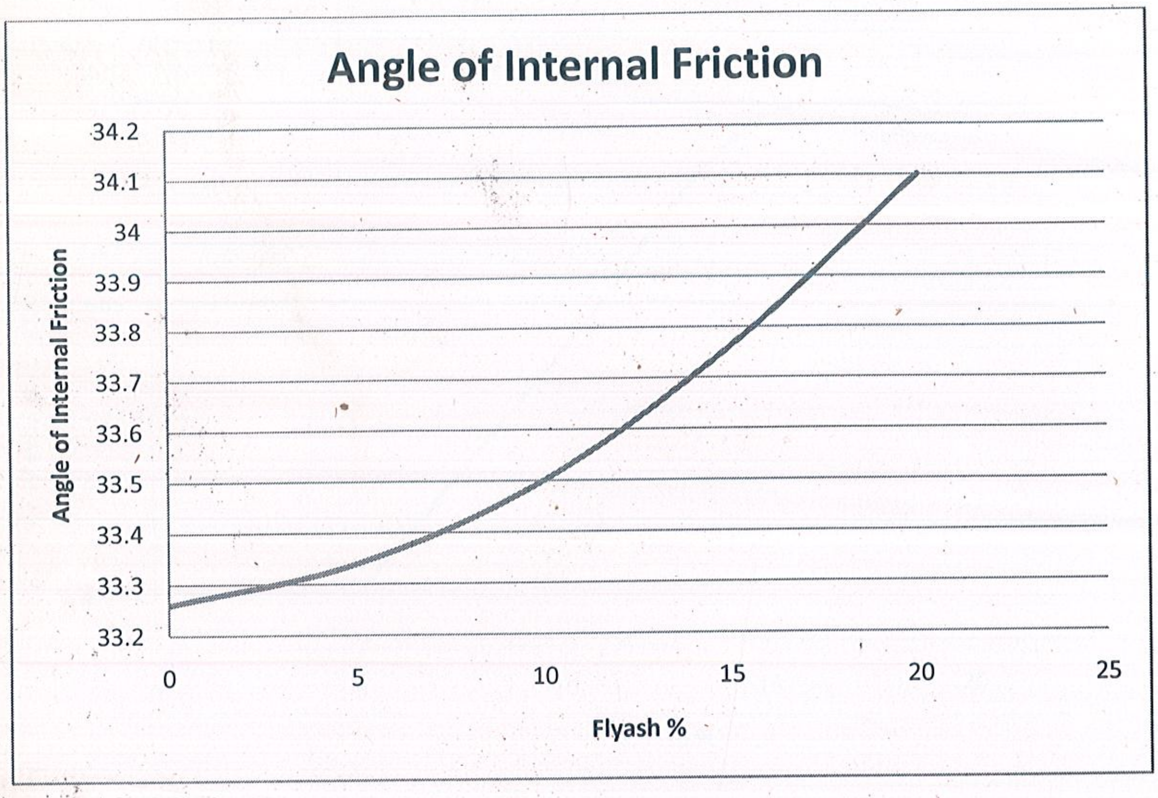

Figure 10 : Variation of Angle of Internal Frictionwith varying Fly ash content.

Graphical representation of variation of Angle of Internal Friction with varying Fly ashcontent.

4.1.5Compaction test with Fly ash

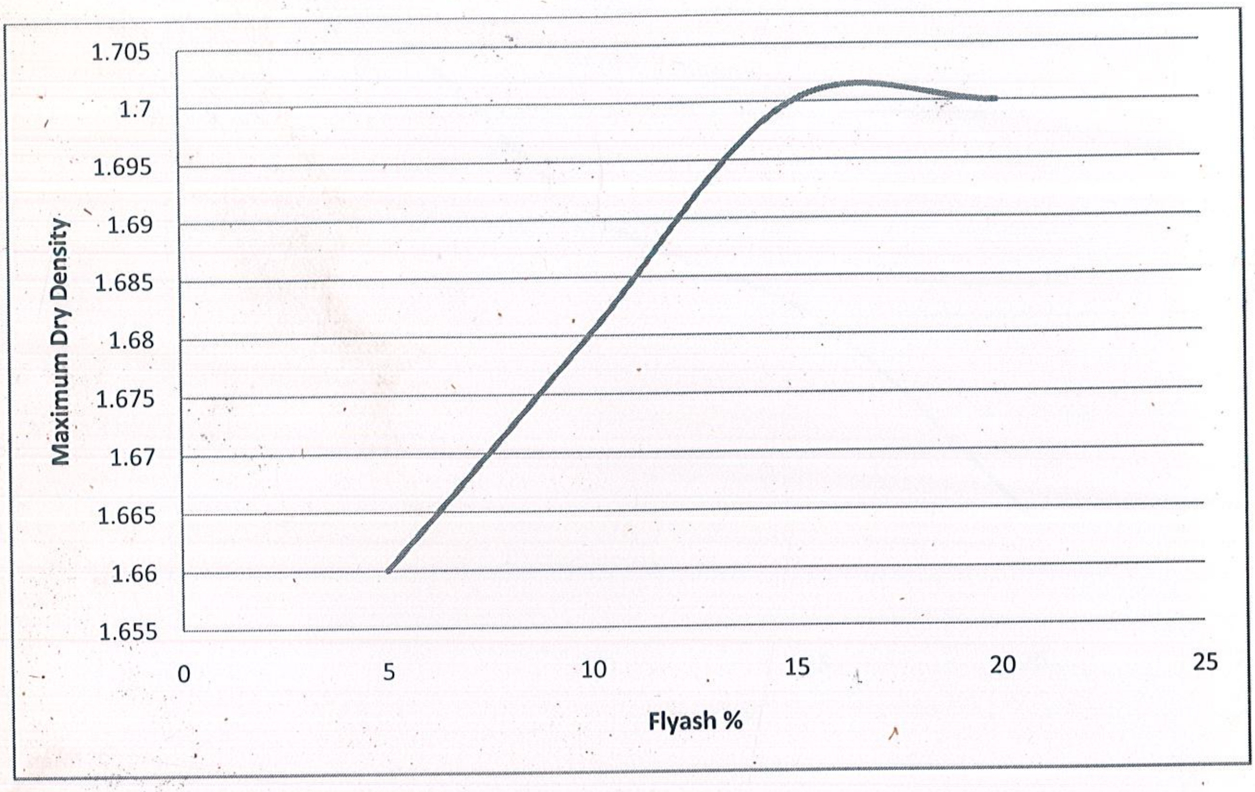

Figure 11 : Variation of maximum Dry Densitywith varying Fly ash content.

Graphical representation of variation in Maximum Dry Density with varying amount of Fly ash.

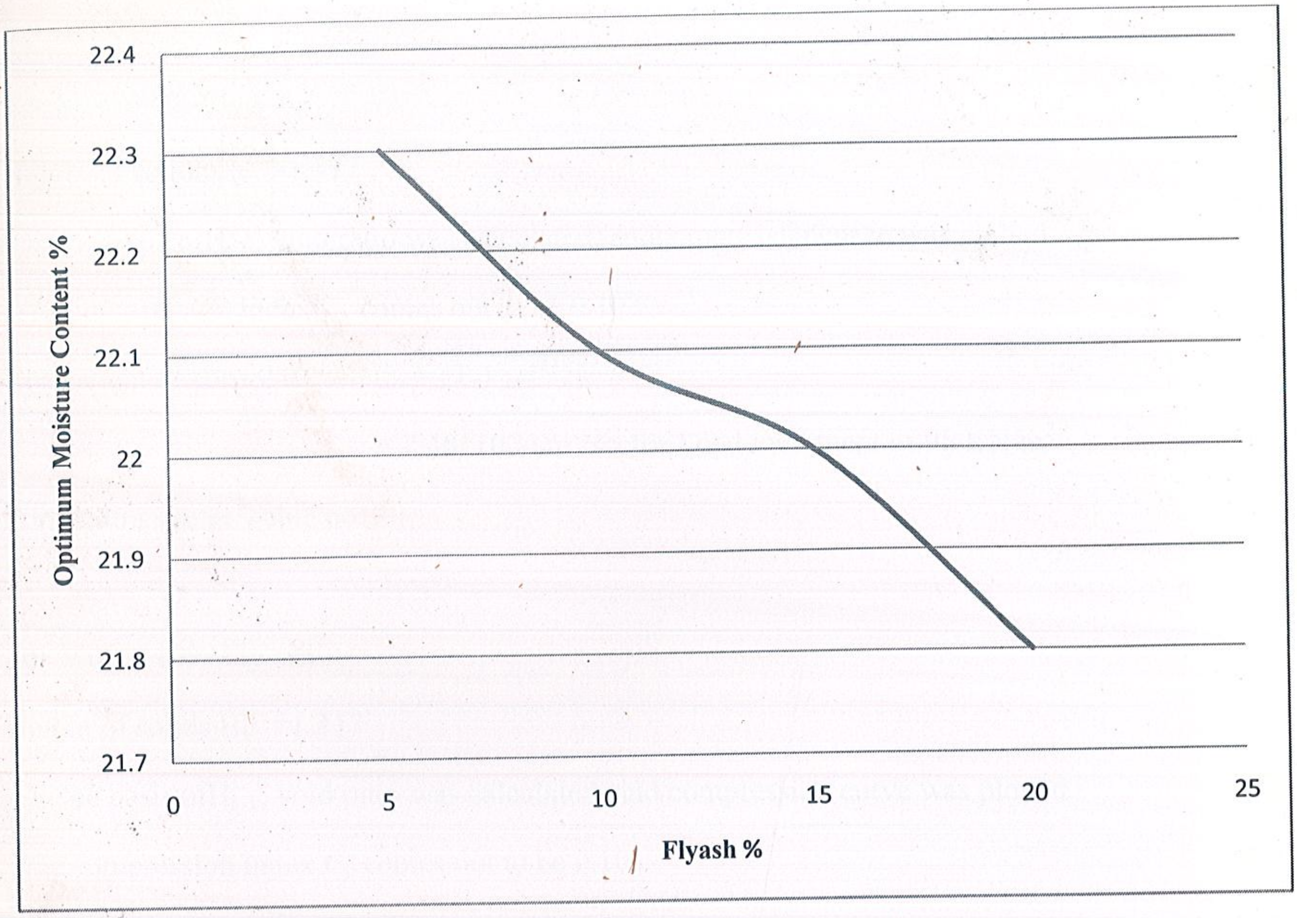

Figure 12 : Variation of Optimum Moisture Contentwith varying Fly ash content.

Graphical representation of variation of,Optimum Moisture Content with varying Fly ash content.

For readings refer Table no. 19

4.1.6 *Consolidation test with Fly ash*

For Mix of 5% Fly ash

Height of solids H_s =1.317

On the basis of H_s, e, void ratio was calculated, andcompressioncurve was plotted

The compression index C_c comes out to be 0.102

Coefficient of consolidation $C_v = (T_v)_{90} d^2 / t_{90}$

$= 7.48*10^{-4}$ cm^2/secfor Load increment of 95 KN/m^2

For readings refer Table no. 20

For Mix of 10% Fly ash

Height of solids H_s =1.317

On the basis of $H_{s,\ e}$, void ratio was calculated, and compression curve was plotted

The compression index C_c comes out to be 0.103

Coefficient of consolidation $C_v = (T_v)_{90} d^2 / t_{90}$

$= 7.43*10^{-4}$ cm^2/secfor Load increment of 95 KN/m^2

For readings refer Table no. 21

For Mix of 15% Fly ash

Height of solids H_s =1.317

On the basis of H_s, e, void ratio was calculated, andcompression curve was plotted.

The compression index C_c comes out to be 0.106.

Coefficient of consolidation $C_v = (T_v)_{90} d^2 / t_{90}$

$= 7.41*10^{-4}$ cm^2/secfor Load increment of 95 KN/m^2

For readings refer Table no. 22

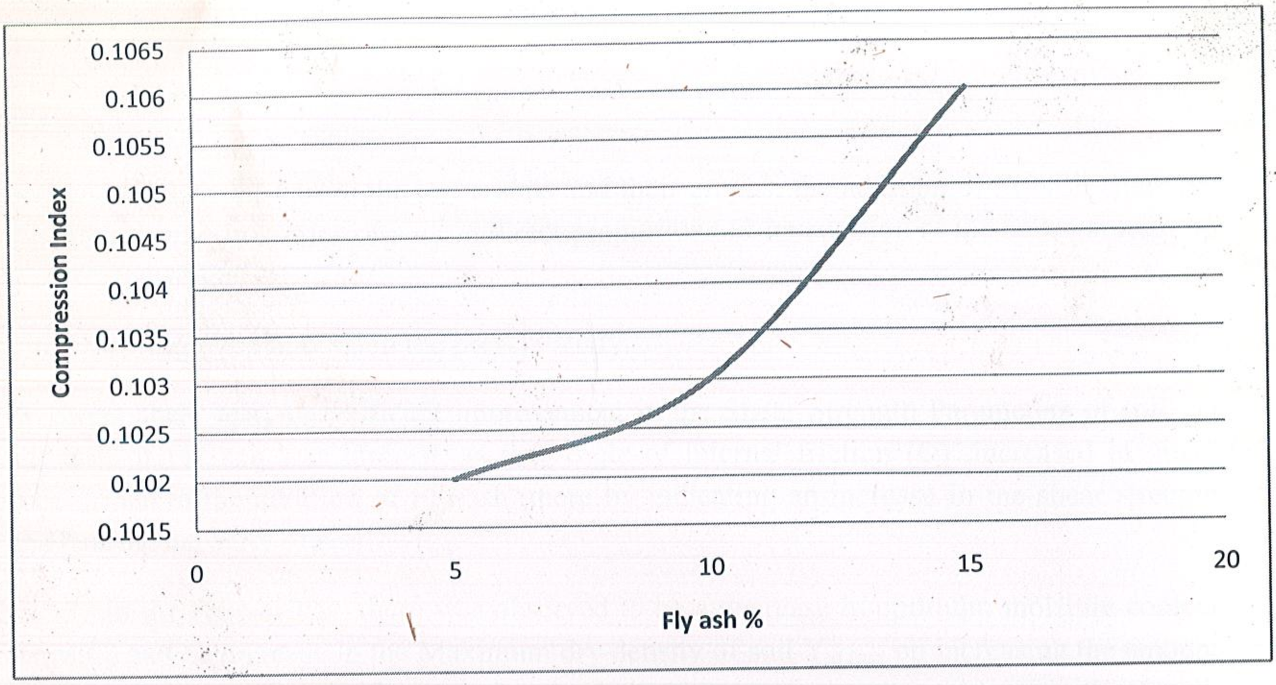

Figure 13 : Variation of Compression Index with varying Fly ash content.

Graphical representation of variation of, Compressive Index with varying Fly ash content.

Since the soil does not possess any cohesion, hence sand replacement method was performed, which was not possible to be performed in the field with varying percentage of Fly ash.

Since Fly ash does not possess any cohesion as well, hence core cutter method was also not possible.

4.2 Analysis of data

As can be interpreted from the test results and their graphs, the addition of Fly ash enhances the engineering properties of soil, in direct proportions of its addition to the soil, at least up to, 20% by weight.

The following were noticed in the present study:

In direct shear test, a significant improvement in the Shear Strength Parameters of soil, on addition of Fly ash was noticed, as the Angle of internal friction (Φ) ,increased in direct proportions to the addition of Fly ash ,there by indicating an increase in the shear strength and bearing capacity of soil.

In the Proctor test, there was observed to be a decrease in optimum moisture content (O.M.C) and an increase in the Maximum dry density of soil $Y_{d\ max}$ on increasing the amount of Fly ash by weight, in the soil thereby indicating an increase in the strength of soil, reduction in shrinkage limit etc.

In the consolidation test, there was observed to be a continuous decrease in coefficient of consolidation C_V of soil, but an increase in the Compression index C_C of the soil, on increasing the amount of Fly ash by weight, thereby indicating a decrease in the compressibility as well as permeability of soil hence, making the soil much more compact and harder.

5.Conclusion

The basic objective of the project was to stabilize the soil of, Waknaghat by using Fly ash as an additive .How the major problem of slope instability of the hilly terrains of Waknaghat, could be tackled using Fly ash.

For stabilizing the soil of Waknaghat, extensive testing was done to find out the properties of the excavated soil, from the hills, in order to study the change in the engineering properties of soil on addition of Fly ash.

After initial testing of soils was over, it was mixed with different percentages of Fly ash and all the tests were again performed, to determine the percentage up to which, Fly ash could be effectively used for the purpose of soil stabilization.

On addition of Fly ash to soil, not much of a change was observed in the values of Specific gravity, Grain size distribution and Bulk density test, but as far as the values of Direct shear, Consolidation, Proctor test and Liquid and Plastic limits were concerned, they showed an improvement over their properties, with continuous increase in the percentage of Fly ash, up to 20%.

Hence it can be concluded that, Fly ashcan improve the properties of Sandy silt soils, and because of its availability in abundance, is a very economical and effective soil stabilizer , and has the potential to replace a lot of other chemical soil stabilizers.

APPENDIX

APPENDIX A

Tables

Sr. No.	Sieve Size	% retained on Sieve	Cumulative %	% Finer
1	10mm	14.2	14.2	85.8
2	4.75mm	12.8	27	73
3	2mm	16	43	57
4	1mm	22.6	65.6	34.4
5	600μ	10	75.6	24.4
6	425μ	6.4	82	18
7	300μ	3.2	85.2	14.8
8	212μ	4.8	90	10
9	150μ	2.2	92.2	7.8
10	75μ	3.6	95.8	4.2
11	Pan	3.4	99.2	0.8

Table 1:Sieve Analysis

Weight Of can	26 gm	27 gm
Weight of water	7 gm	8 gm
Weight of can + dry soil	49 gm	54 gm
Weight of can + wet soil	56 gm	62 gm
Number Of Blows	27	28
Moisture Content	30.4%	29.62%
Liquid Limit	30.06%	30.06%

Table 2:Liquid Limit

Weight of can	**28 gm**	**27 gm**
Weight of water	1 gm	1 gm
Weight of can + dry soil	32 gm	31 gm
Weight of can + wet soil	33 gm	32 gm
Plastic Limit	25%	25%

Table 3:Plastic Limit

Sample Weights (Grams)	**W1**	**W2**	**W3**	**W4**
	467	670	1383	1273

Table 4: Specific Gravity

Sr. No.	**Normal Stress**	**Shear Stress**
1	0.5	0.312
2	1	0.656
3	1.5	0.982
4	2.0	1.315

Table 5:Direct Shear Test

Applied pressure	Compression(ΔH) cm	Specimen height	$e=H/H_s-1$	Δe (a)
0.5	0.044	1.956	0.48	-0.02
1	0.065	1.935	0.49	-0.01
2	0.081	1.919	0.45	-0.02
4	0.131	1.901	0.42	-0.10
8	1.13	0.87	-0.33	-0.11

Table 6:Consolidation Test

% Fly ash	W1	W2	W3	W4	S.G
0	467	670	1383	1273	2.17
5	479	683	1381	1270	2.18
10	481	681	1381	1272	2.18
15	479	678	1380	1269	2.2
20	480	679	1380	1270	2.2

Table 7:Specific Gravity test with varying percentage ofFly ash

Weight of can(gm)	28	30
Weight of can+ dry soil(gm)	52	53
Weight of can+ wet soil(gm)	59.2	59.93
Number of blows	28	28
Moisture content (%)	29.99	30.12
Liquid limit (%)	30.33	30.47

Table 8:Liquid limit with 5% Fly ash

Weight of can	25	27
Weight of can +dry soil(gm)	52	54
Weight of can+ wet soil(gm)	60.4105	62.2107
Number of blows	30	29
Moisture content (%)	31.15	30.41
Liquid Limit(%)	31.73	30.86

Table 9:Liquid limit with 10% Fly ash

Weight of can	**26**	**27**
Weight of can +dry soil(gm)	56	55
Weight of can+ wet soil(gm)	65.63	64.02
Number of blows	32	34
Moisture content (%)	32.09	32.15
Liquid limit (%)	32.91	33.17

Table 10:Liquid limit with 15% Fly ash

Weight of can	**26**	**29**
Weight of can +dry soil(gm)	57	61
Weight of can +wet soil(gm)	67.3106	81.36
Number of blows	35	34
Moisture content (%)	33.26	33.38
Liquid limit (%)	34.42	34.44

Table 11:Liquid limit with 20% Fly ash

Weight of can(gm)	**28**	**30**
Weight of can +dry soil(gm)	31.4	35.22
Weight of can +wet soil	39.73	44.33
Plastic limit (%)	25.74	25.88

Table 12:Plastic limit with 5% Fly ash

Weight of can(gm)	26	29
Weight of can +dry soil(gm)	35.41	37.11
Weight of can+ wet soil(gm)	44.70	46.93
Plastic limit(%)	26.23	26.46

Table 13:Plastic limit with 10% Fly ash

Weight of can(gm)	27	29
Weight of can+ dry soil(gm)	33.51	34.26
Weight of can+ wet soil(gm)	42.59	43.67
Plastic limit (%)	27.09	27.46

Table 14:Plastic limit with 15% Fly ash

Normal Stress (kg/cm^2)	Shear Stress(kg/cm^2)
0.5	0.333
1	0.658
1.5	0.991
2	1.314

Table 15:Direct Shear test performed with 5% Fly ash

Normal Stress(kg/cm^2)	Shear stress (kg/cm^2)
0.5	0.332
1	0.662
1.5	0.993
2	1.327

Table 16:Direct Shear test performed with 10% Fly ash

Normal stress(kg/cm^2)	Shear stress(kg/cm^2)
0.5	0.336
1	0.668
1.5	1.001
2	1.379

Table 17:Direct Shear test performed with 15% Fly ash

Normal Stress (kg\cm^2)	Shear stress(kg/cm^2)
0.5	0.337
1	0.677
1.5	1.015
2	1.38

Table 18:Direct Shear test performed with 20% Fly ash

%Fly ash	O.M.C (%)	Maximum dry density(gm/cm^3)
5	22.3	1.66
10	22.10	1.68
15	22	1.70
20	21.8	1.70

Table 19: Compaction test with Fly ash

Applied pressure	Compression(ΔH) cm	Specimen height	e=H/H_s-1	Δe (a)
0.5	0.015	1.985	0.507	-0.017
1	0.017	1.9.83	0.505	-0.00 2
2	0.071	1.929	0.464	-0.041
4	0.112	1.888	0.433	-0.031

Table 20: Consolidation properties with 5% Fly ash

Applied pressure	Compression(ΔH) cm	Specimen height	e=H/H_s-1	Δe (a)
0.5	0.012	1.998	0.517	-0.027
1	0.016	1.984	0.506	-0.011
2	0.066	1.847	0.466	-0.040
4	0.109	1.891	0.435	-0.031

Table 21:Consolidation properties with 10% Fly ash

Applied pressure	Compression(ΔH) cm	Specimen height	$e=H/H_s-1$	Δe (a)
0.5	0.009	1.991	0.511	-0.021
1	0.014	1.986	0.485	-0.026
2	0.064	1.936	0.470	-0.015
4	0.105	1.895	0.438	-0.032

Table 22:Consolidation properties with 15% Fly ash

Appendix B

Lab Equipments

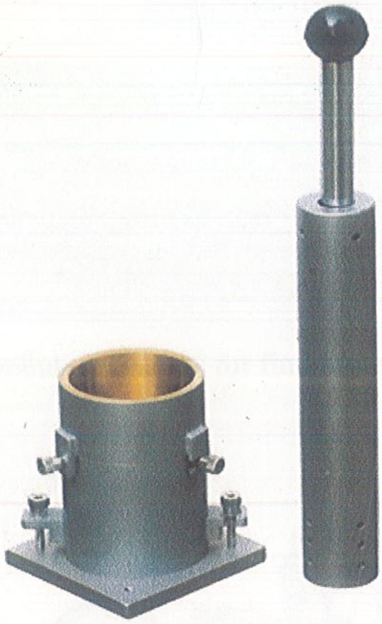

Image 1: Proctor test apparatus ,used for finding Optimum Moisture Content and Maximum Dry Density of soil

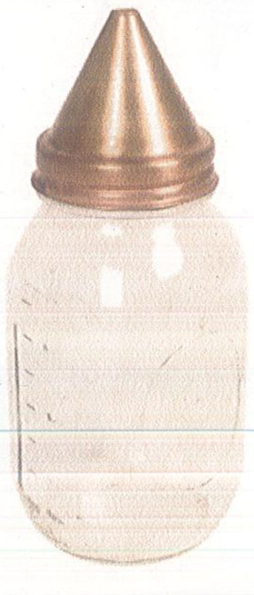

Image 2:Pyconometer jar used for finding the Specific gravity of soil

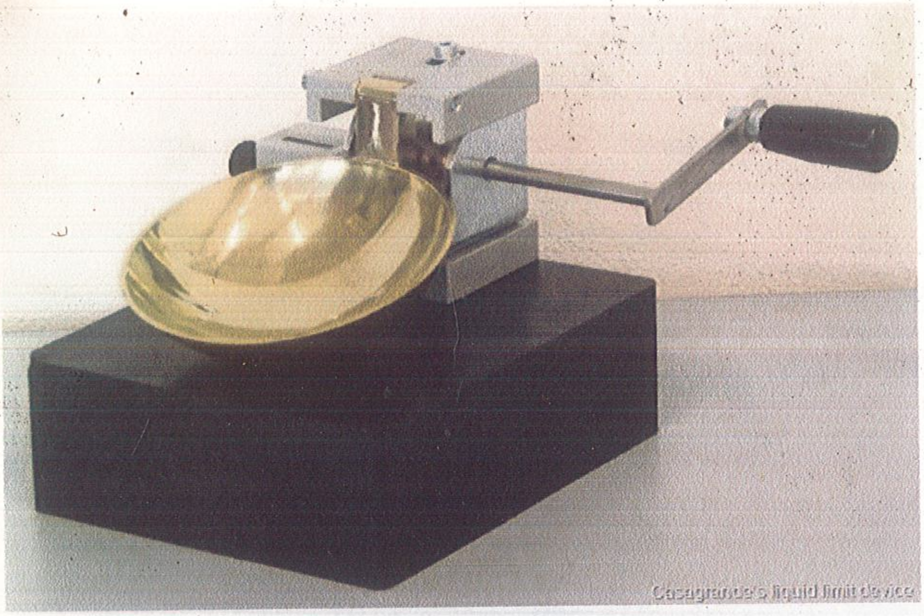

Image 3:Casagrande apparatus for finding Liquid Limit of soil

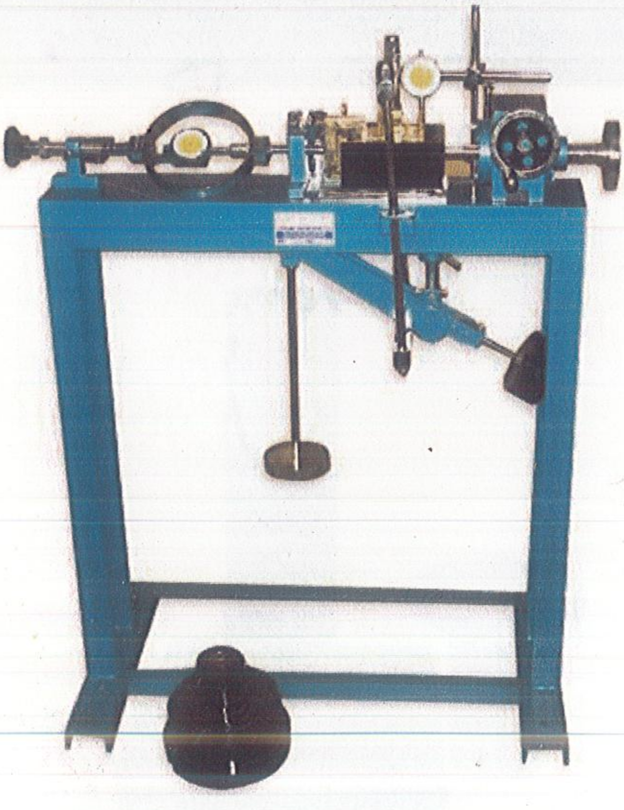

Image 4: Direct Shear test apparatus used for finding, angle of internal friction of soil

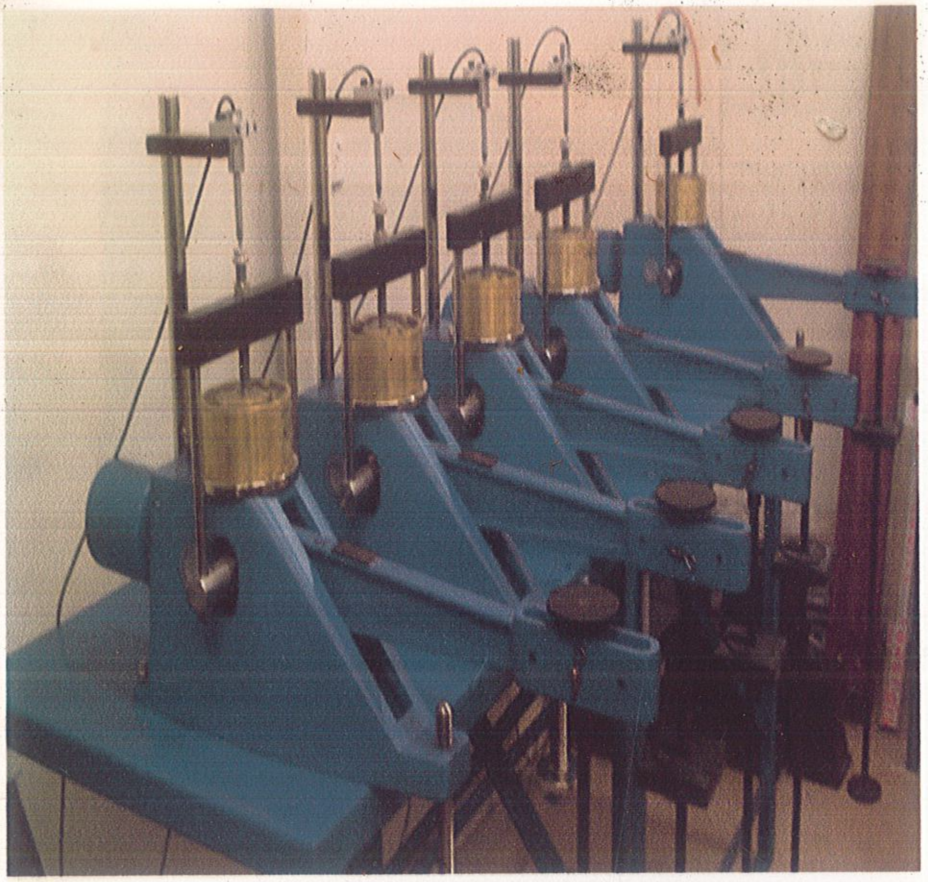

Image 5:Consolidation test apparatus used for finding Coefficient of consolidation and Compression index of soil

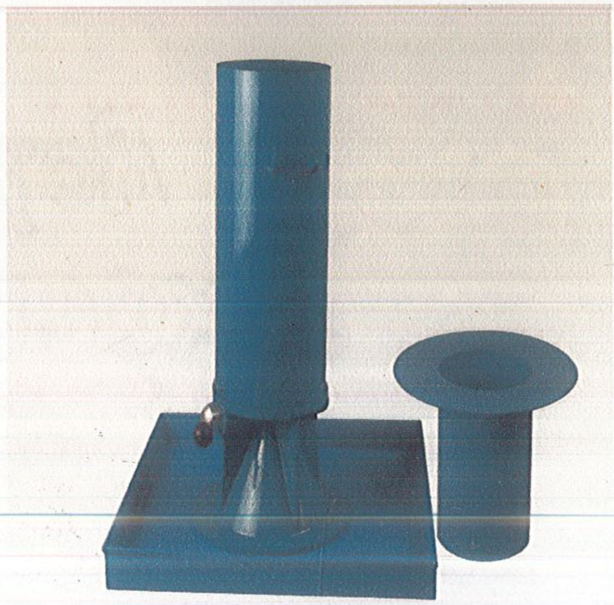

Image 6:Sand Replacement apparatus used for finding the density of soil

Image 7: Class F Fly ash generated in power plant

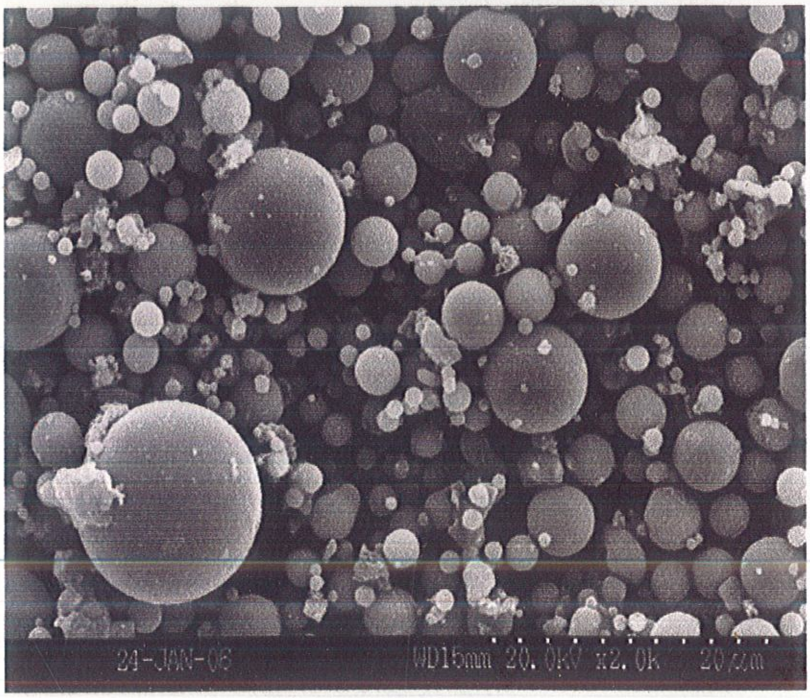

Image 8: Microscopic view of class F Fly ash

Appendix C

Definitions of Basic Terms

Soil – sediment or other accumulation of solid particles produced by physical or chemical disintegration of rocks. May or may not contain organic material.

Atterberg Limits – They are the basic measure of the nature of fine grained soil. Depending on the water content of the soil it may appear in four states : solid, semi – solid , plastic and liquid. In each state the consistency and behavior is different. The boundary between each state can be defined based on a change in soil behaviour.

Plastic Limit-The boundary between the plastic and the semi-solid states of the soil.

Liquid Limit-The boundary between liquid and plastic states of the soil.

Both expressed as moisture content percentage (by weight).

Stabilizing additives – It is a mechanical, chemical or bituminous additive used to maintain or increase the strength and durability, decrease the moisture content or improve the engineering properties of the soil.

Impermeability – The relative resistance to the passage of air/water into a material.

Geotextiles - Permeable textiles which can either be biodegradable or non-biodegradable used in conjunction with soils, as an integral part of manmade project.

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