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Improvement of Shear Strength of Sandy Silt Soil by Mixing Optimum Percentage of Fly Ash: A Study

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Abstract: Strength of soil is very important parameter for any civil construction. Soft and weak soil is more liable to differential settlements, less shear strength and high compressibility. Hence it is necessary to check and improve bearing strength of soil. Different types of soil have different strength. Soil strength can be increased or decreased by mixing some material with the soil like fly ash, lime, silica fume, plastics, synthetic fibers, reinforcement fibers etc. This paper represents the shear strength parameters of sandy silt soil by blending with fly ash in different proportion. Soil is mixed with fly ash at 5%, 10%, 15%, and 20%. The Optimum Water Content increases and Dry Density decreases with increases in fly ash due to progressive increasing silt particles in soil. The shear strength of the soil enhance due to presence of fly ash. So, fly ash has a potential to improve engineering characteristics of sandy silt soil. Hence the main objective of this work is to utilize industrial waste like fly ash to improve the strength of sandy silt soil with its optimum percentage of fly ash. The cohesion is maximum for 5% fly ash in granular soil mixture and is decreased gradually and attains maximum value for 15% fly ash granular soil mixture. This study revealed that Fly Ash content more than 15% may not probably cause any additional improvement for the stabilized soil
Key words: Fly ash, Cohesion, Angle of internal friction, sandy silt soil, Optimum Water Content, Dry Density, Permeability, mix proportion.

I. INTRODUCTION

When designing and constructing highways or more generally any super structures on Sandy silt soil, it is essential to make sure that the foundation soil is stable and provides good support to the applied loads. Sandy soil are known to spread in huge areas throughout the country in which thousands of miles of new roads, highways, buildings, hydraulic structures etc are being constructed every year. Replacing such kind of weak soil is not an economically feasible alternative since it is very costly; besides, the replacement soil is not always available in nearby sites. This study discusses the possibility of Sandy silt soil stabilization using Fly ash as the stabilizing agent. Various ratios of Fly Ash content mixed with sandy silt soil are used to examine the improvement of engineering properties of Sandy silt soil in terms of shear strength parameters. The results indicate that mixing Sandy silt soil with Fly Ash as a stabilizing agent would influence the engineering properties of soil. It is determined that the fly ash stabilization of Sandy silt soil improves the strength characteristics of the soil so that it becomes usable as a base material for civil construction and proper foundation material for other types of super structures.

This study deals with the stabilization of sandy soils through the application of fly ash. Soil stabilization simply means the permanent physical and chemical alteration of soils to enhance their physical and engineering properties.

The main aim of this study is to determine the percentage of fly ash that would be added to a sandy soil to obtain the optimum stability of the soil. In order to achieve this, the following tests will carried out: Sieve analysis, Compaction test, triaxial shear strength test. Sieve analysis is carried out purposely to determine the percentage of different grain sizes contained within a sandy soil. On the other hand, Compaction test is carried out in order to determine the maximum dry density and optimum moisture content of the sandy soil and lastly, triaxial shear strength test is carried out to determine the cohesion (c) and internal friction angle (ϕ) of the sandy soil sample with the addition of fly ash in percentages as a stabilizing agent.

According to the previous study, Singh (1996) studied the unconfined compressive strength of fly ashes as a function of free lime present in them. It was found that fly ash having higher free lime content shows higher strength. Gray and Lin (1972) have reported that fly ashes have the requisite properties for use in highway sub-bases. Joshi et. al. (1975) have carried out

CBR tests on fly ash samples compacted at optimum moisture content and maximum dry density and reported the soaked CBR to range between 10% to 18%. Toth et. al. (1988) reported the CBR of fly ashes to vary between 6.8 – 13.5 % for soaked condition and 10.8 – 15.4 % for unsoaked condition.

Pandian & Krishna (2001) have reported the beneficial aspects of fly ash soil mixes in road construction. In this paper, the strength characteristics of fly ash and fly ash-lime stabilized soils have been investigated.

Aksoy, H.S., Gor, M. studied on sand dunes properties are stabilized by using Portland cement, fly ash and silica fume. In order to find out which additive caused maximum dry density, soil samples were prepared by using four different replacement amounts of 0%, 3%, 5% and 10% by weight of soil. Maximum dry densities and optimum moisture contents were determined for all mixtures. It is concluded that dune samples have adequate density when compacted with 10%

Stabilization of soils with cement has positive impact on environment (Andromalos et al. 2000).

Fast and well-known method for determining strength properties is obtaining Mohr-Coulomb parameters. In this theory shear strength is assumed to vary linearly due to applied normal stress in accordance with two commonly know parameters as the cohesion (*c*) and the internal friction (*φ*). Tests which were carried out by many researches (Ismailet al. 2002, Lo et al. 2003) based on triaxial tests. Difficulty and sophistication of triaxial equipment leads researches to find other methods of obtaining Mohr-Coulomb model parameters (Piratheepan et al. 2012). One of this ways is unconfined compressive strength test (UCS). This method however has its weak points. It has been well discerned that Mohr-Coulomb envelope becomes non-linear in low confi ning stress. This fact results in decrease of cohesion and increase of friction angle. For cemented sands this rule leads to significant over estimation of the cohesion.

According to this theory, mechanical prosperities are bounded with cohesion and friction. In case of simple loading of soil sample with applied stress (*σ*), the shear stress (*τ*max) is presented from Coulomb theory.

Cement treated soils which are used in road construction are characterized by the increase of strength. Simple method to find this occurrence is unconfined compressive strength test (UCS). The following relationships proposed by Thompson (1966) can be used to define the cohesion and modulus of elasticity of lime treated soils based on unconfined compressive strength.

Observation of increasing mechanical parameters lead to conclusion that fine-graded soils yields a substantial increase in cohesion and less improvement in internal friction angle (Thompson 1966, Muhunthan and Sariosseiri 2008). This statement indicates that stabilization displays brittle behavior.

Cement treated soils exhibit signifi cant increase in compressive strength under UCS test, which varies from 40 times for fine-graded soils to 150 times for coarse-graded soils (Mitchell 1976).

Because of brittle characteristics of soil stabilized with cement, which manifest as curing time increases, unconfined compressive strength increases, while the decrease of strain adequate to peak stress can be a statement that behavior of soft clay changes from normally consolidated to over consolidated (Bergado et al. 1996).

This fact states stabilized soils with cement as soft rock corresponded with this material by brittle and higher tensile strength than porous materials. Tensile strength of stabilized soils is problematic because it often gives different results of internal friction angle and cohesion for the same material (Muhunthan and Sariosseiri 2008).

Industrial wastes (e.g., fly ash, slag, and mine tailing) have been blended with lime and cement to improve the geotechnical properties of roadway subgrade

(Balasubraniam et al. 1999; Kaniraj and Gayathri 2003; Bin- Shafique et al. 2010; Rahmat and Kinuthia 2011).

Another waste that has potential for alternative materials is rice husk. Rice husk is abundant in rice-producing countries such as Indonesia, Thailand, Philippines, and many others (Hwang and Chandra 1997). It is sometimes burnt for parboiling paddy in rice mills. The partially burnt rice husk will contribute to environmental pollution. Significant efforts has been devoted not only to overcome the pollution problem but also to increase its added value by using it as substituting or secondary materials for limited-availability conventional materials.

During the last few decades, research has been carried out to investigate the utilization of rice husk ash as a stabilizing material in soil improvement (Lazaro and Moh 1970). Much research (e.g., Lazaro and Moh 1970; Rahman 1987; Ali et al. 1992a; Basha et al. 2005; Hossain 2011) has shown that rice husk ash (RHA) is a promising secondary material to improve lime or cement-stabilized soils. Addition of rice husk ash in lime or cement-stabilized soils enhanced the compressive strength significantly (Balasubramaniam et al. 1999; Muntohar and Hashim 2002; Muntohar 2002). However, the stabilized soil exhibited brittle-like behavior (Muntohar 2002; Basha et al. 2005). The brittleness of the stabilized soil may be suppressed by inclusion of discrete elements such as fibers. Stabilized and reinforced soils are composite materials that result from an optimum combination of the properties of each individual constituent material. A well-known approach in this area is the use of fibers and cemented materials in composites. Experimental verification reported by various researchers (e.g., Messas et al. 1998; Muntohar 2000; Consoli et al. 2002; Ghiassian et al. 2004; Kaniraj and Gayathri 2003; Cavey et al. 1995) has shown that the fiber reinforced soils are potential composite materials, which can be advantageously employed in improving the structural behavior of stabilized and natural soils. Other researchers (Consoli et al. 1998; Kaniraj and Havanagi 2001; Tang et al. 2007) have successfully used fiber reinforcement in a cement-stabilized soil. Fieldwork experience suggests that it is easier to control the fiber content in comparison with its length. Longer fiber will be more difficult to uniformly distribute in the soil–fiber interface and resulting slippage plane in the soil. Thus, it was suggested to limit the fiber length to be less than 50 mm in length (Al-Refei 1991; Santoni et al. 2001; Jiang et al. 2010). Previous studies have indicated that the fiber content is the most controlling strength parameter (Consoli et al. 2002; Gaspard et al. 2003; Muntohar 2009).

II. MATERIALS AND METHODS

A. *Materials*

1) *SOIL:* Local soil is collected from Lashkar Gwalior. Soil sample is yellow in color and sandy in nature.
2) *FLY ASH*: Fly ash is collected from **Parichha Thermal Power Station** is located at Parichha in Jhansi district in the Indian state of Uttar Pradesh, about 25 km from Jhansi on the bank of Betwa River. The power plant is owned and operated by Uttar Pradesh Rajya Vidyut Utpadan Nigam.The fly ash is in grey color and pozzolanic in nature the most common composition of fly ash are SiO2, Al2O3, Fe2O3, MgO, CaO, SO3, organic carbons and others.

B. *Methods*

Due to lose particle of sandy silt soil has poor strength so need to stabilize the soil been occurred. To find out the effect of fly ash on sandy silt soil varying amounts [100% soil, soil +5 % fly ash, soil + 10% fly ash, soil + 15% fly ash, soil + 20% fly ash] is utilized. And local available soil, Parichha thermal power plant fly ash samples and soil mixed samples containing fly ash of 5, 10, 15, and 20 % on the basis of dry weight.

Each soil mix underwent rigorous laboratory test: particle sieve analysis to find out the Type and Class of the soil, Specific Gravity , Atterberg Limits Tests to determine Liquid Limit , Plastic Limit and Plastic Index of soil, Standard Proctor test which determine the Maximum Dry Density and Optimum Water Content, Falling Head Permeability test by which coefficient of permeability is obtained. Triaxial shear test is performed to determine cohesion c and internal friction angle ϕ.

III. EXPERIMENTS

Following experiments have been performed. These entire tests were conducted both on local soil and fly ash mixed soil for determining physical properties and engineering properties. The test are-

A. Grain Size Analysis.
B. Specific Gravity Test.
C. Liquid Limit and Plastic Limit Test.
D. Standard Proctor Compaction Test.
E. Falling Head Permeability Test.
F. Triaxial Shear Test

IV. RESULTS AND DISCUSSION

After carrying out the above tests, observations were noted and considered and it is discovered that 15% fly ash has the highest impact in the increment of the compressive strength of the sandy silt soil and will be most suitable for the stabilization of sandy soil. So therefore, we recommend the addition of 15% fly ash to the sandy soil to be used on site for maximum stability

Table 1 Physical property of sandy silt soil and fly ash

Physical Properties	Test Results	
	Soil	Fly ash
Grain Size		
Sand (%)	72.1	32.2
Silt (%)	25.7	62.6
Clay (%)	2.2	5.2
Color	Yellow	Grey
Uniformity Coefficient (Cu)	18.5	-
Coefficient of curvature (Cc)	0.38	-

Classification of Soil	SM	Sandy Loam
Name of Soil group	Gap graded coarse soil	-
Specific Gravity	2.62	2.2
Liquid limit (%)	12	-
Plastic limit (%)	Non Plastic	Non Plastic
Plasticity	Non Plastic	Non Plastic
Coefficient of Permeability, K cm/s	3.92x10-5	1.8x10-6
Compaction Maximum Dry Density MDD (KN/m³) Optimum Water Content, OMC (%)	19.5 10	16.2 24
Triaxial parameters C Φ	10 37.5	12 28

V. DISCUSSION

The discussions are based on the laboratory tests conducted on different geotechnical parameters and its results.
Effects of fly ash on soil and its engineering properties and physical properties are discussed here.

A. Grain size

According to results soil is not well graded, soil is sandy silt and soil is impervious in nature. Soil comes in SM class, but as fly ash is added it change its class from SM to ML.

B. Specific Gravity

According to table 1, Specific gravity of soil is 2.62 and specific gravity of fly ash is 2.2. Hence after mix different percentage of fly ash in soil the specific gravity of soil is decreases from 2.62 (0% FA) to 2.34 (20%FA).

C. Atterberg limits

These limits are used to denote the degree of firmness of a soil.The soil is sandy silt so it is non plastic in nature. Also the fly ash is non plastic. Hence the plastic limit and plastic index cannot be determined.Hence when compare the sandy silt soil and mixture of soil – fly ash having same plastic limit (non plastic), it is found that as the liquid limit is increases, the permeability is decreases.

D. Compaction characteristics

The soil has a Maximum Dry Density of 19.5 kN/m³ at Optimum Moisture Content 10 %. Fly ash exhibit maximum dry density of 16.2 kN/m³ at Optimum Moisture Content 24 %. The 5, 10,15, 20% fly ash-soil mixture exhibit a decrease of Maximum Dry Density with increasing Optimum Moisture Content .

E. Permeability

The hydraulic conductivity (k) values of soil samples, fly ash and soil-fly ash mixed samples. The hydraulic conductivity for the local sandy silt- soil is 3.92×10-5 cm/sec. With the increase of fly ash contents in mixed samples, the rate of permeability decreasing. The hydraulic conductivity values are within the range of 3.92 ×10-6 and 4.9×10-6 with percentages of fly ash 5, 10, 15 and 20%.

F. Triaxial Shear Test

The values of angle of internal friction and cohesion to percentage of fly ash from 0% to 20% are tabulated in table .From the test

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results the variation of cohesion with the percentage of fly ash is studied and is shown in fig. 7.The cohesion is maximum for 5% fly ash granular soil mixture and is decreasing gradually and attains maximum value for 15% fly ash granular soil mixture. The values of angle of internal friction and cohesion with different percentage of fly ash are shown in the following figures.

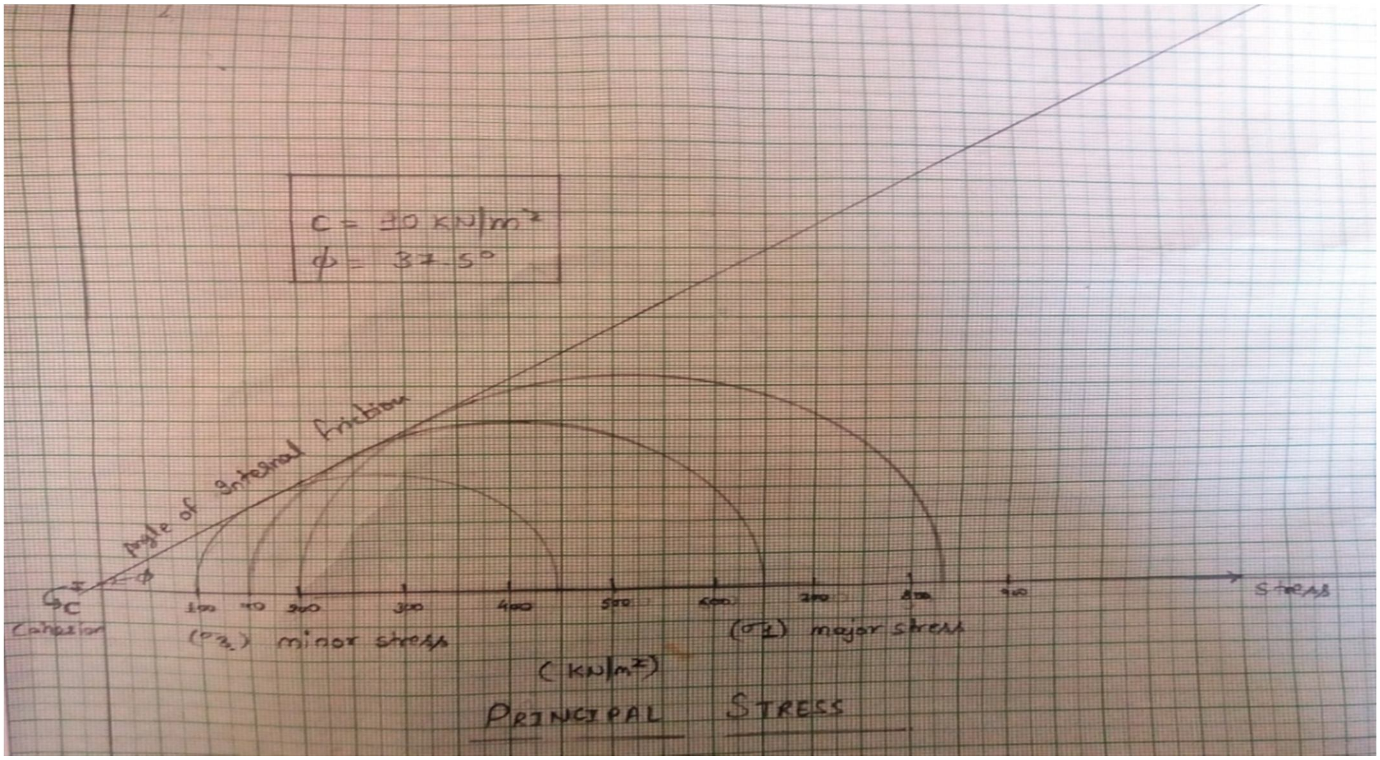

Figure 1 Mohr's circle of sandy silt soil

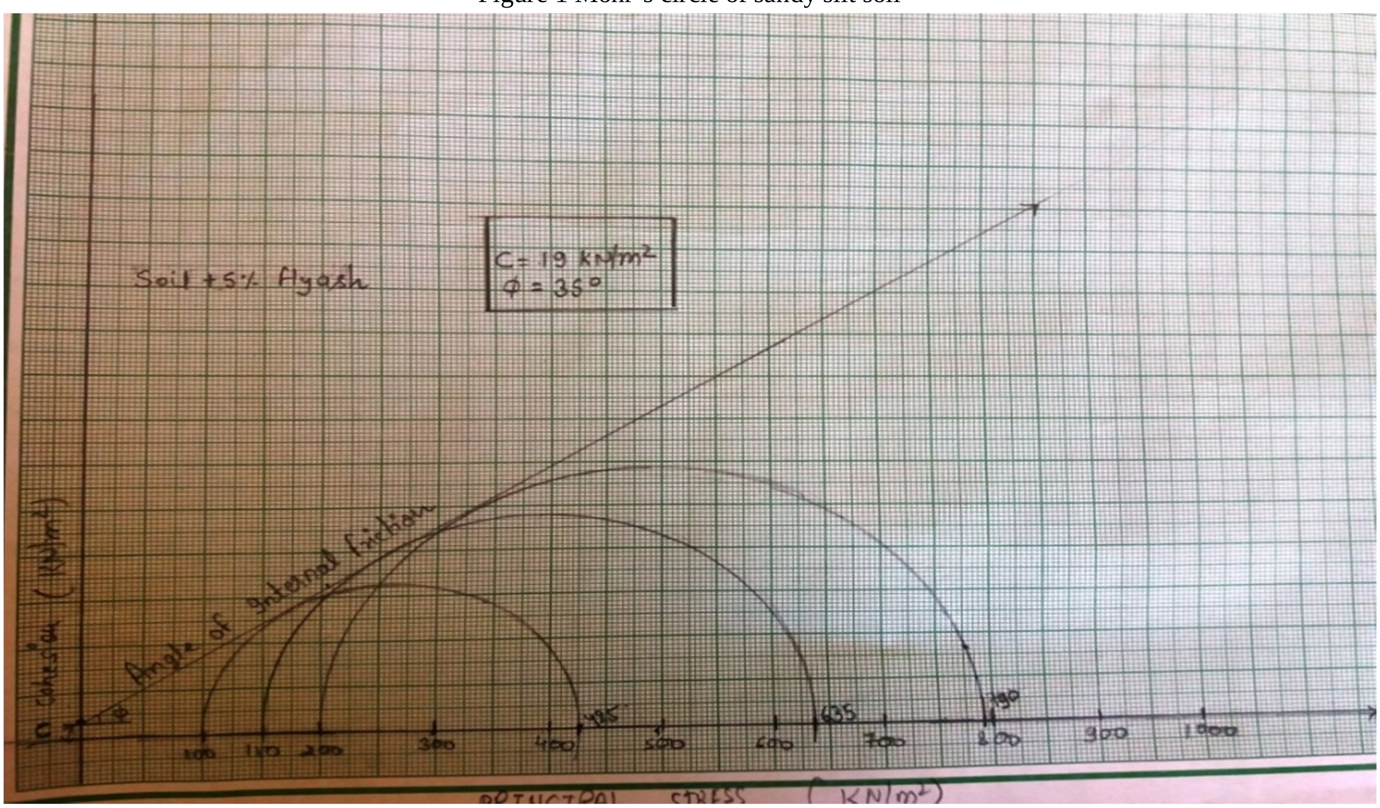

Figure 2 Mohr's circle of sandy silt soil +5% fly ash

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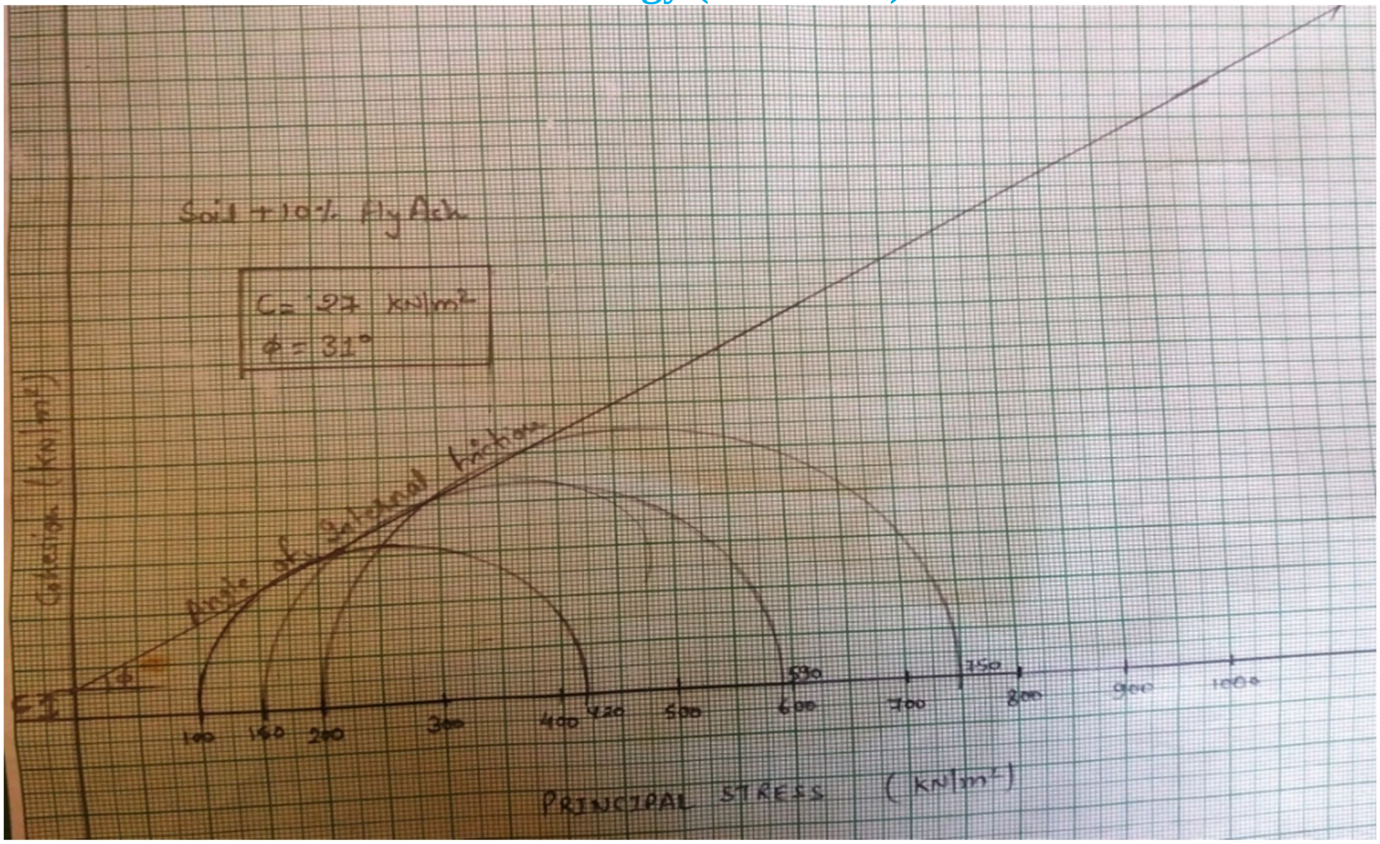

Figure 3 Mohr's circle of sandy silt soil +10% fly ash

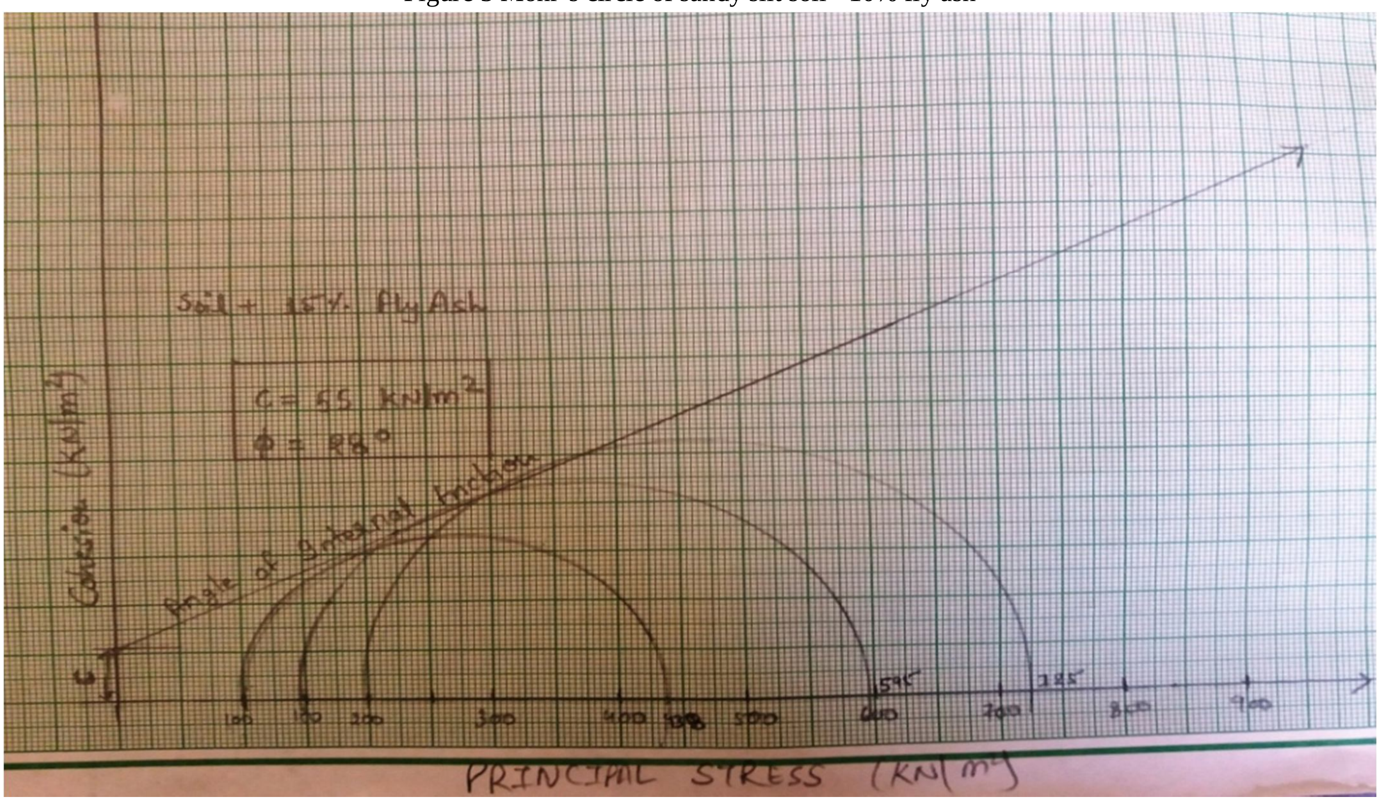

Figure 4 Mohr's circle of sandy silt soil + 15% fly ash

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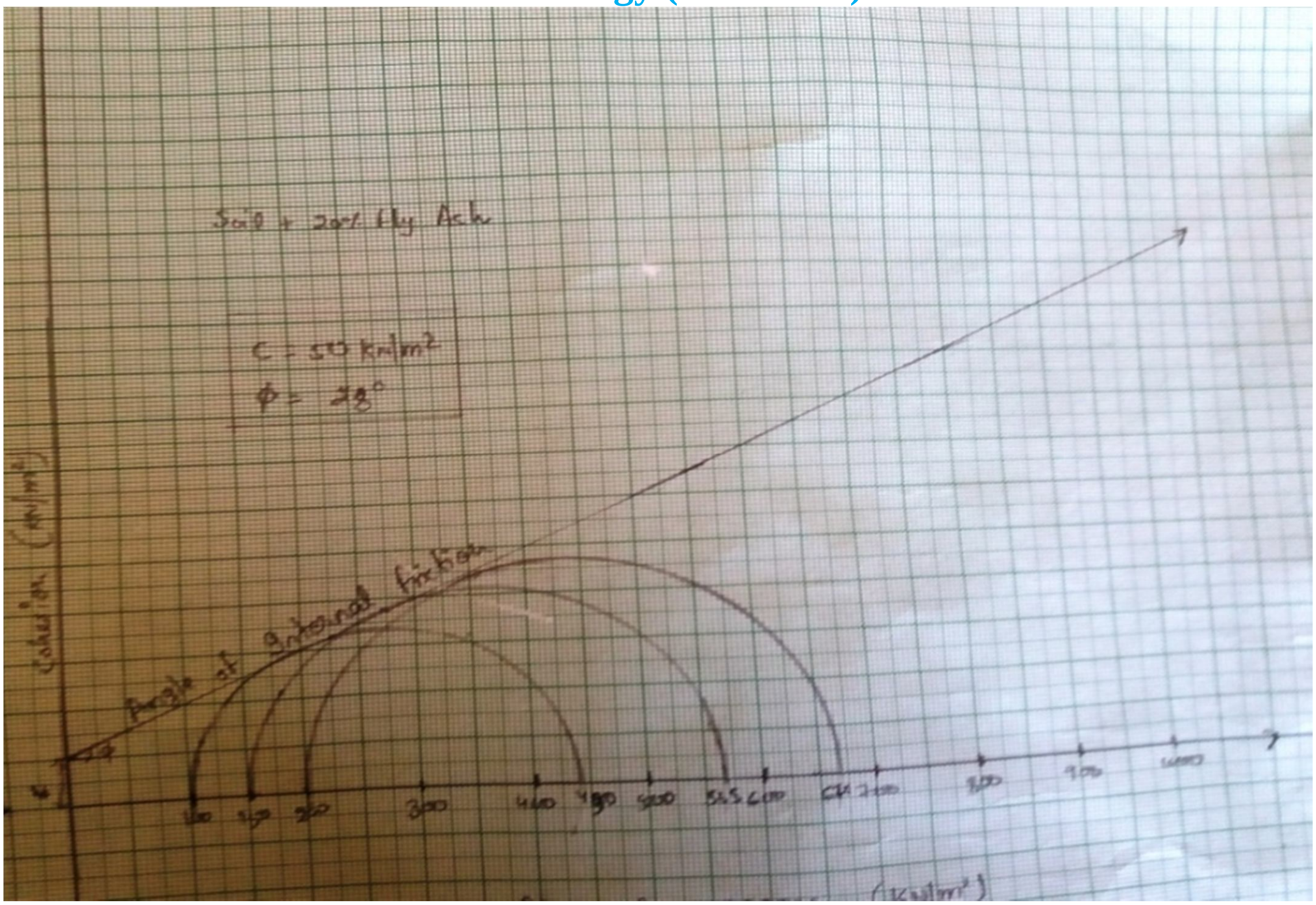

Figure 5 Mohr's circle of sandy silt soil + 20% fly ash

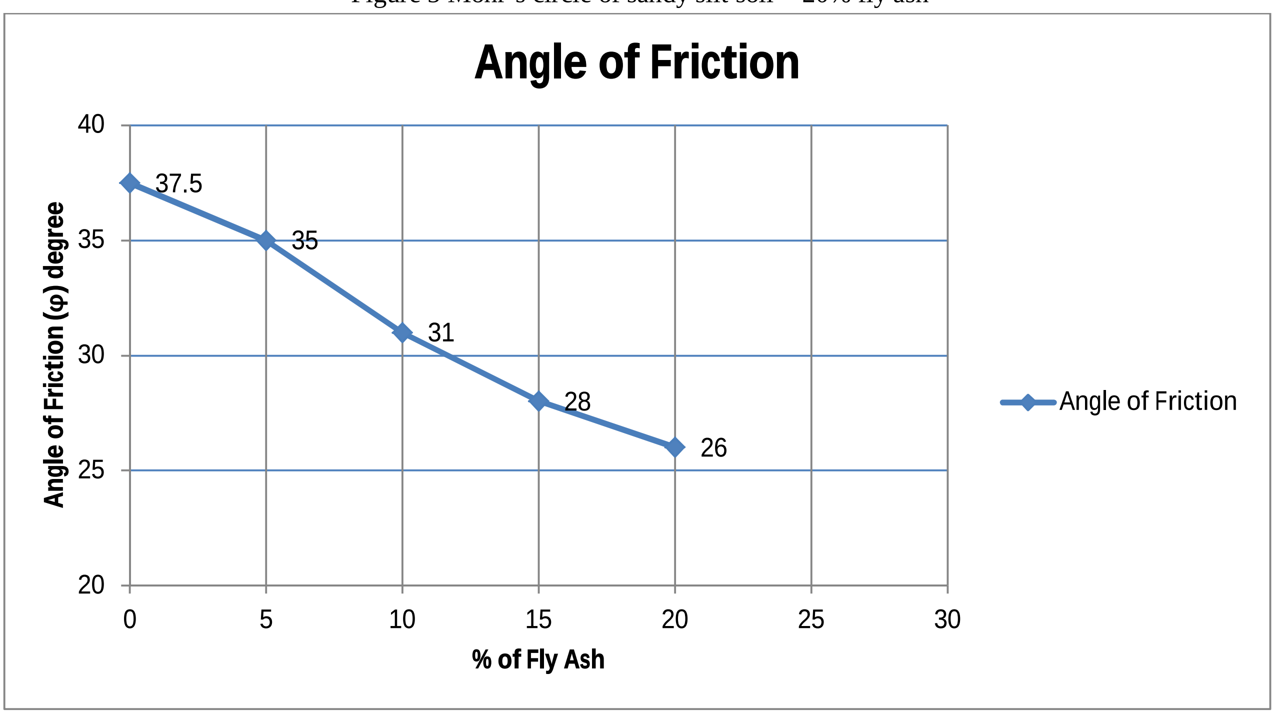

FIGURE 6 (Internal friction angle Vs % of Fly Ash in Soil)

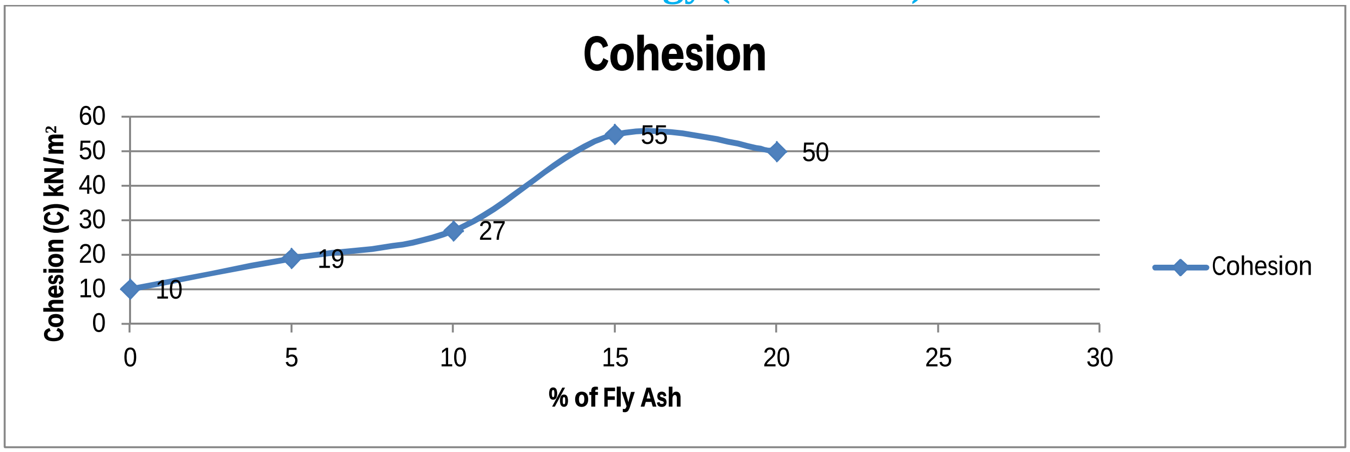

Figure 7 (Cohesion Vs % of Fly Ash in Soil)

VI. CONCLUSION

Following conclusions may be made based on the above test results and discussions:

A. The specific gravity of sandy silt soil decreases as we increase the percentage of fly ash in the sandy silt soil.

B. The liquid limit of sandy silt soil increases when percentage of fly ash increased in the sandy silt soil.

C. The sandy silt soil is non plastic, remains non plastic when fly ash is added because fly ash is also non plastic.

D. Soil-fly ash mixtures exhibit well-defined moisture density relationship, varying the mixture percentage. As the fly ash content increases optimum moisture content increases and maximum dry density decreases. The dry unit weight for soil-fly ash is lesser than those of typically compacted soil.

1) The higher silt content and lesser plasticity of the fly ash result in lesser volume change of the soil.

2) The rate of permeability of sandy silt soil decreases with increase of fly ash in soil.

3) The cohesion is maximum for 5% fly ash granular soil mixture and decreasing gradually and attains maximum value for 15% fly ash granular soil mixture. The values of angle of internal friction and cohesion with different percentage of fly ash.

4) Fly ash with high percentage silt content can be mixed in local sandy silt soil; this material may be used as land filling and embankments in the field of geotechnical engineering construction.

VII. ACKNOWLEDGMENT

At this moment of accomplishment, first of all I pay homage to my guide, **Dr. M.k.Trivedi**. This work would not have been possible without his guidance, support and encouragement. Under his guidance I successfully overcame many difficulties and learned a lot. He used to review my thesis progress, give his valuable suggestions and made corrections. His unflinching courage and conviction will always inspire me, and I hope to continue to work with his noble thoughts. I can only say a proper thanks to him through my future work.

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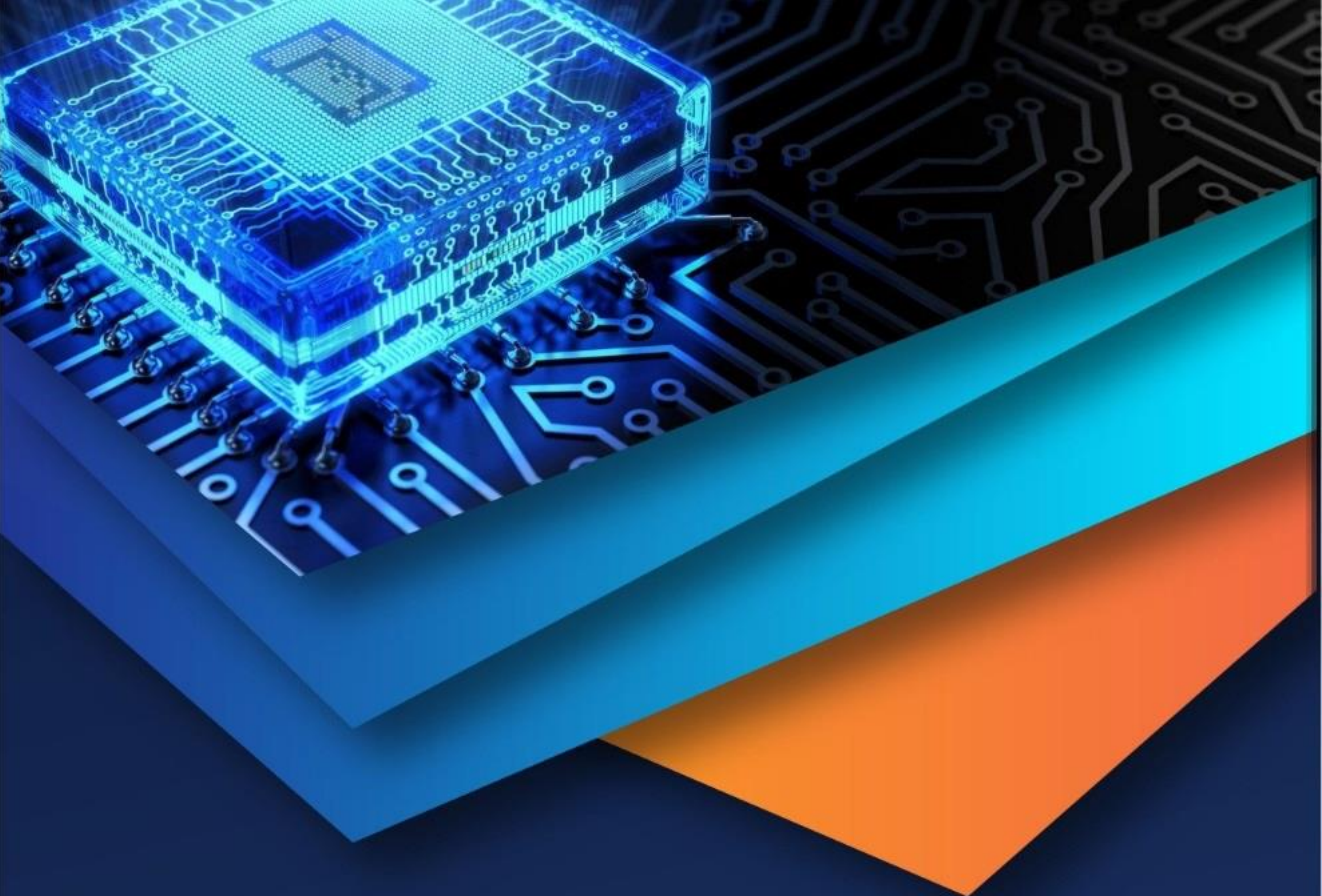

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