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Strength and Compressibility Characteristics of Peat Soil

S. Karthigeyan(1)
Associate Professor
Department of Civil Engineering
CEG, Anna University
Chennai, India

A. Ramachandran(2)
PG Student
Department of Civil Engineering
CEG, Anna University
Chennai, India

***Abstract*- Peat soil is a very soft soil with low shear strength, high organic matter, and high compressibility exists in unconsolidated state. These characteristics of soils can cause an excessive settlement which is very challenging to geotechnical engineers and the construction industry at large for construction in this type of soils. The main focus of the present paper is to discuss the strength and compressibility characteristics of stabilized peat soil by using lime and flyash based on various laboratory test results. The unconfined compressive strength of stabilized peat soil using fly ash increases with increase in percentage of fly ash and same trends are observed for the lime treated soils. The compression characteristics of treated peat soils are improved due to the influence of lime and flyash. Primary compression and secondary compression is found to decrease for the treated peat soil as compared to an untreated peat soil.**

Keywords - Peat soil, lime, flyash, Unconfined Compressive Strength (UCS), compressibility, Maximum Dry Density (MDD), Optimum Moisture Content (OMC).

I. INTRODUCTION

In today's scenario, due to increase in population and demand for social improvements there is a scarcity of stable ground for the construction of new buildings and development of new infrastructure. So, it is unavoidable to construct new structures in weak and problematic soils. Therefore, it is necessary to improve the properties of problematic soils before construction by using various ground improvement techniques. In practice, there are several methods used for improving the geotechnical properties of soils such as, deep and dynamic compactions. Also, soil properties are improved by providing a proper drainage system, stone column, geosynthetics, deep mixing of admixtures and chemical stabilization. Organic soils are generally formed in natural environment and do not allow for rapid decaying of material. Soil with organic content greater than 20 % is said to be organic soils and more than 75 % considered as peat soils. Peat soil is formed naturally by an incomplete decomposition of plant and animal constituent under anaerobic condition at low temperature. Peat is classified in to three classes such as fibric, hemic and sapric based on the degree of decomposition. Further often reduced to three classes such as fibrous, semi-fibrous, and amorphous based on fibre content [8]. Due to the problematic nature of peat soil, construction on it becomes very difficult. Hence, engineers regarded peat soil as the worst foundation soil for supporting the structures [1].

Due to the above, significant research was gone into solving this issue and it highlights the following; many research works and laboratory tests were conducted to determine the properties of prepared peat soil specimens with varying proportions of lime [3]. It is reported that the maximum dry density increases at low optimum moisture content. The unconfined compressive strength of stabilized peat soil increases with increase in lime percentage but after the optimum percentage of lime content, strength began to drop. It is observed that the peat soil stabilized with ordinary Portland cement performs better than other admixtures [2]. The peat soil stabilized with the mixture of flyash and lime shows an increase in unconfined compressive strength with increase in curing periods [7]. Some researchers used gypsum and flyash mixture for stabilization of peat soil [5] and reported that the unconfined compressive strength of stabilized peat increased with increase in proportions of gypsum – flyash mixture and cutting period.

There are lots of research studies about the strength characteristics of stabilized peat soil using various stabilizing agents but very limited literature are available on the compressibility characteristics of peat soil. Further, it is revealed from literature that the degree of stabilization achieved by using cement is of higher order as compared to other admixtures. In view of the above, an attempt is made in this paper to understand the unconfined compressive strength and compressibility characteristics of both untreated and treated peat soil using lime, flyash and lime-fly ash mixture.

II. MATERIALS AND METHODS

Peat soils were collected from Kodaikanal region, Tamilnadu, India. The climatic factors such as temperature, humidity and rainfall are the most important factors for the formation and development of peat soil in this region [4]. These factors are found to influence directly and indirectly on peat soil characteristics. The peat soil collected from this region consists of partially decomposed and semi-fibrous in nature. Hence, it can be classified as Hemic peats. The physical properties of peat soil consists of organic content, particle size distribution, specific gravity and Atterberg limits were evaluated as given in Table I. Liquid limit is found to be more than 50 % hence, the soil is classified as highly compressible organic soil (OH). It can be seen from the table that only 3 % of the particle is gravel and rest of the major particle is sand having more than 80 %.

TABLE I. INDEX PROPERTIES OF VIRGIN PEAT SOIL

Properties	Values
Specific gravity, G	2.3
Silt	13 %
Fine sand	32 %
Medium sand	42 %
Coarse sand	10 %
Gravel	3 %
Liquid limit	55 %
Organic content	35 %

Fly-ash pertaining to class ‘C’ type was collected from Ennore thermal power plant at Chennai, India. The lime with calcium hydroxide $Ca(OH)_2$ was used as other admixture to stabilize the peat soil. Series of laboratory tests were conducted on virgin peat soil and stabilized peat soil with varying proportions of lime, flyash and lime – flyash mixture. Standard proctor test, Unconfined compressive strength test and Consolidation tests were conducted to determine the engineering properties of virgin peat and stabilized peat soils. The engineering properties of treated peat soil using various admixtures are compared with untreated peat soil and discussed in the paper.

III. RESULTS AND DISCUSSION

The engineering properties of virgin peat soil and the effect of fly ash, lime and fly ash-lime mixture on strength and compressibility characteristics of stabilized peat soil are discussed in the following section based on the laboratory test results.

A. *Compaction characteristics:*

Based on the standard Proctor test results, compaction curves were drawn for peat soil with varying proportions of lime and flyash as shown in Fig. 3.1 and 3.2 respectively. It is seen from the Fig.3.1 that maximum dry density of treated peat soil with lime is increasing with increase in percentage of lime content but there is no significant change in optimum moisture content. It can be seen from the Fig.3.2 that the maximum dry density of treated peat soil using fly ash shows an increase with increase in percentage of fly ash. But, there is a reduction in optimum moisture content with increase in percentage of fly ash as observed.

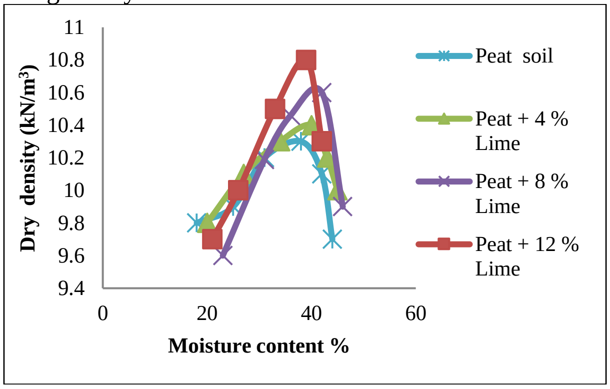

Fig. 3.1 Compaction curves of peat soil with varying percentage of lime

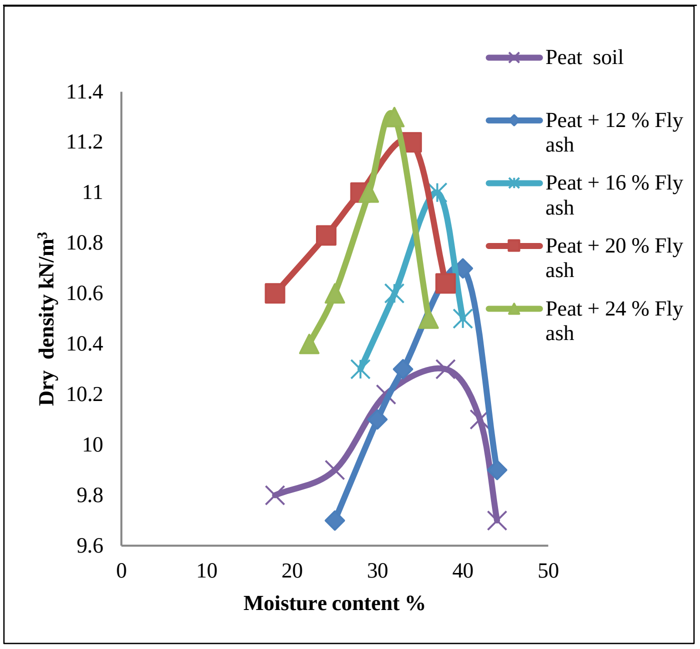

Fig. 3.2 Compaction curves of peat soil with varying percentage of fly ash

B. *Unconfined compressive strength:*

Unconfined compressive strength tests were carried out on virgin peat soil and treated peat soil with varying percentage of lime and fly ash. Based on the tests, the results were interpreted to predict the stress-strain behavior and strength for peat soil treated with different mix proportions of lime and fly ash. Figs. 3.3 and 3.4 show the stress strain curves of treated peat soil with varying mix proportions of lime and fly ash respectively.

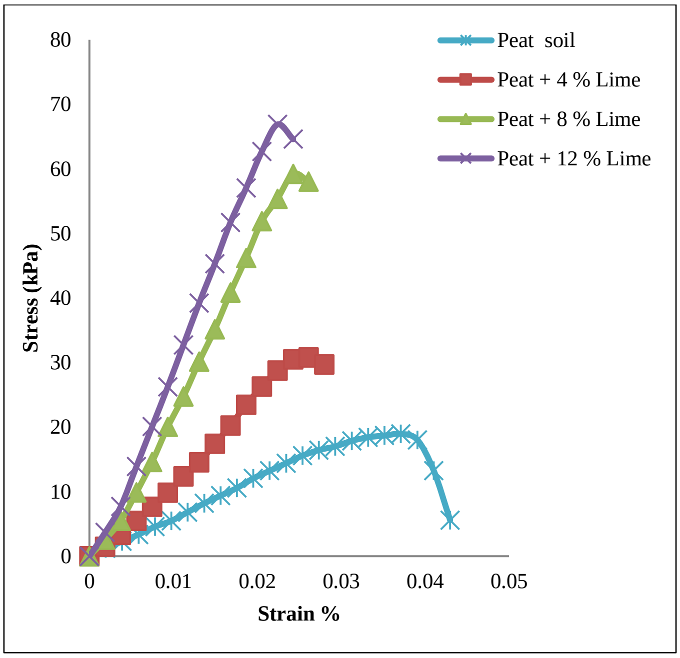

Fig. 3.3 Stress - strain curves of treated peat soils with varying mix proportion of lime

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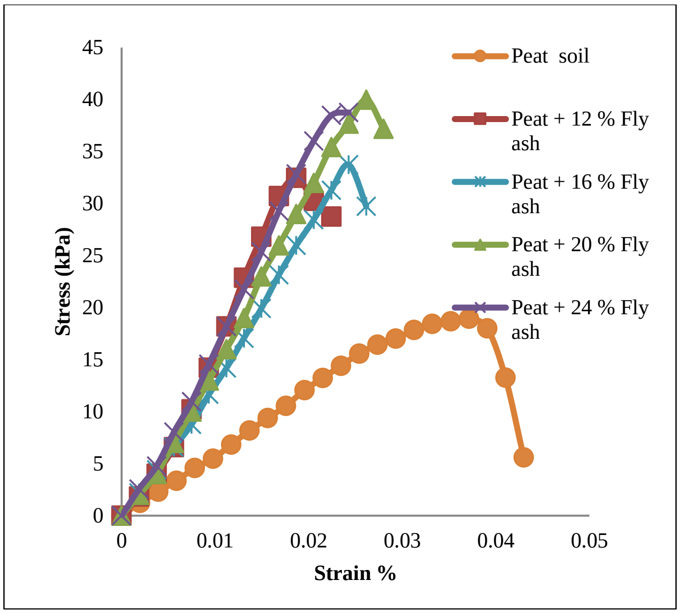

Fig.3.4 Stress – strain curves of stabilized peat soil using flyash with varying mix proportion

It can be seen from the figures that there is an enhancement in strength on addition of lime and flyash in varying proportions. On compared to flyash, lime yields more strength because of the presence of more calcium ions. This is due to the development of good bonding between the soil grains which leads to enhancement in strength because of the pozzolanic reaction.

C. Effect of lime – fly ash mixture on the compaction and UCS:

It is observed from the Fig. 3.3 and Fig. 3.4, that the UCS value for stabilized peat soil with only lime and only flyash shows significant improvement in strength between 8 to 12 % and 16 to 20 % respectively. In view of this, compaction and UCS tests were conducted on peat soil with lime - flyash mixture by keeping flyash percentage as constant and varying the percentage of lime (i.e. 20 % fly ash and varying percentage of lime). Simliar kind of tests were carried out by keeping the lime percentage as constant and varying the percentage of flyash (i.e 12 % lime and varying the percentage of flyash). Fig.3.5 show the compaction curves of treated peat soil with varying proportion of flyash – lime mixture by keeping the percentage of lime as constant. Also, Fig.3.6 show the compaction curves of treated peat soil with varying proportion of flyash – lime mixture by keeping the percentage of flyash as constant. It can be seen from Figs. 3.5 and 3.6 that the maximum dry density is achieved for peat soil treated with 12 % lime – 20 % fly ash mixture.

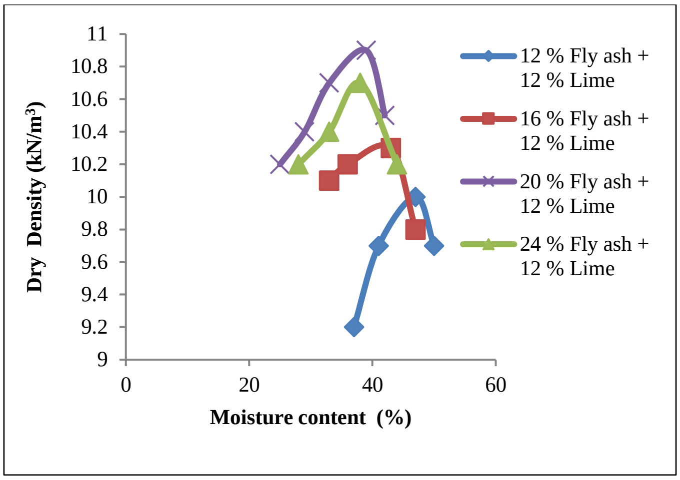

Fig. 3.5 Compaction curves of peat soil with varying proportion of fly ash- lime mixture by keeping lime percentage as constant

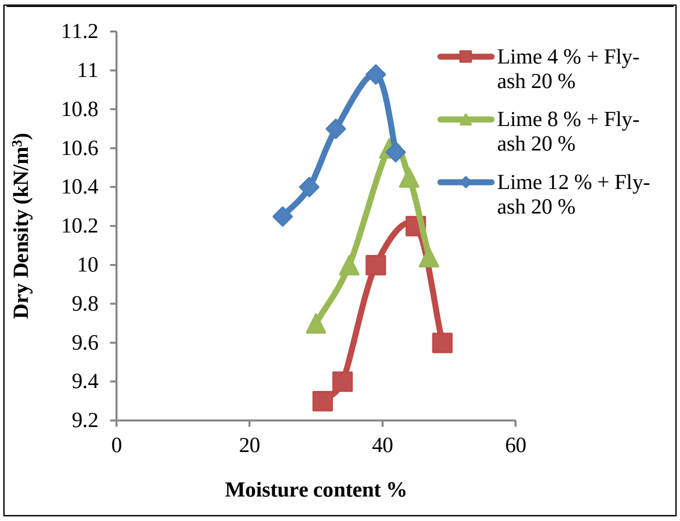

Fig.3.6 Compaction curves of peat soil with different proportion of flyash-lime mixture by keeping flyash percentage **as** constant

Series of Unconfined Compressive Strength (UCS) tests were conducted on stabilized peat soil with respect to varying mix proportion of lime- flyash mixture. Based on these tests, results were interpreted to predict the stress-strain behavior of stabilized peat soil for different mix proportions. Figs. 3.7 and 3.8 show the stress – strain curves of treated peat soil with varying mix proportions of lime- flyash mixtures. It is observed from these figures that the unconfined compressive strength of peat soil increased with varying proportions of lime – flyash mixture. The unconfined compressive strength of virgin soil is compared with stabilized peat soil using different lime– fly ash mixture as shown in Table II.

International Journal of Engineering Research & Technology (IJERT)
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Vol. 8 Issue 12, December-2019

TABLE II. UNCONFINED COMPRESSIVE STRENGTH OF STABILIZED PEAT SOIL

Mix proportions	Unconfined compressive strength (kPa)
Virgin soil	19
Soil + 4 % Lime + 20 % Fly ash	77
Soil + 8 % Lime + 20 % Fly ash	81
Soil + 12 % Lime + 12 % Fly ash	77
Soil + 12 % Lime + 16 % Fly ash	99
Soil + 12 % Lime + 20 % Fly ash	141
Soil + 12 % Lime + 24 % Fly ash	112

It is observed from the Table II ,that the peak stress for stabilized peat soil using the mix proportion of 12 % lime + 20 % fly ash yielded high unconfined compressive strength of 141 kPa. It is evident from the Figs. 3.7 and 3.8 that the unconfined compressive strength of peat soil increases with an increase in percentage of fly ash- lime mixture.

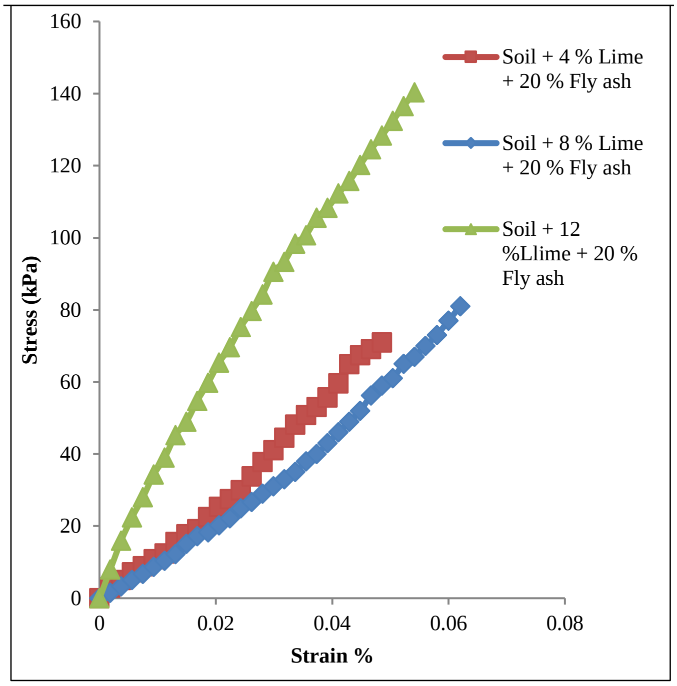

Fig.3.7 Stress – strain curves of stabilized peat soil using different Proportion of fly ash-lime mixture

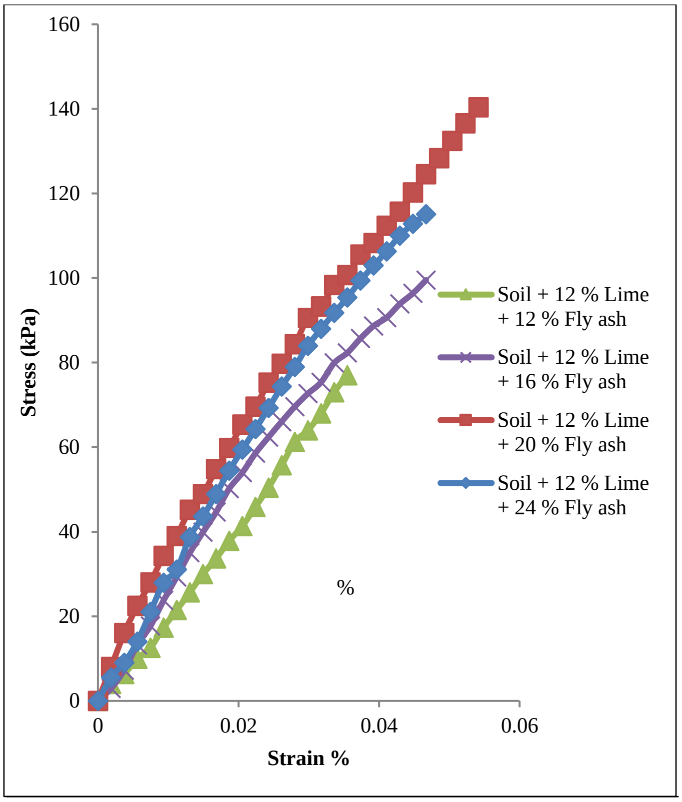

Fig. 3.8 Stress – strain curves of stabilized peat soil using different Proportion of fly ash – lime mixture

D. Compressibility characteristics of peat soil:

Since peat soil is highly compressive in nature, it is necessary to study the compressibility characteristics of peat soil. The compression behavior of peat soil is different from the clay soil. Initial compression occurs instantaneously after the load being applied, the primary and secondary compression are time dependent. A series of consolidation tests were carried out to evaluate the compressibility characteristics of stabilized peat soil by using only lime and only fly ash. From the unconfined compressive strength test results, a significant increase in strength is observed at 12 % lime and 20 % fly ash. Thus, the compressibility characteristic of peat soil was stabilized with an addition of 12 % of only lime and 20 % of only fly ash. Based on the test results, various plots such as void ratio versus effective stress curve and compression versus square root time curves were drawn to evaluate the compression index and coefficient of consolidation. Figs. 3.9 to 3.11 show the void ratio versus effective stress curves for peat soil, peat soil stabilized by 12 % lime and 20 % fly ash respectively. Figs. 3.12 to 3.14 show the compression versus square root time curves for peat soil, peat soil stabilized by 12 % lime and 20 % fly ash respectively.

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Void ratio versus effective stress curve:

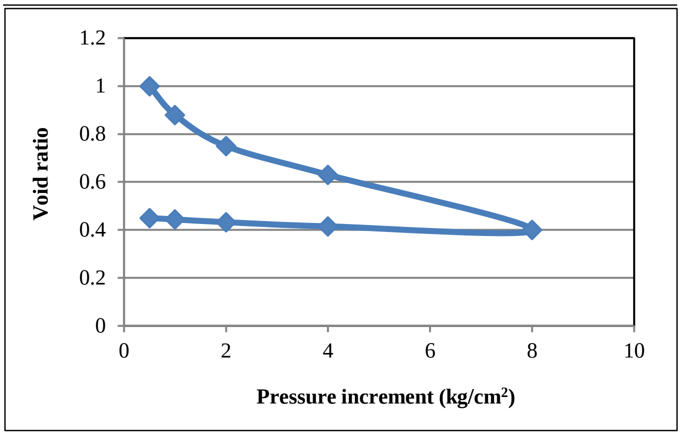

Fig. 3.9 Void ratio versus effective stress curve for peat soil

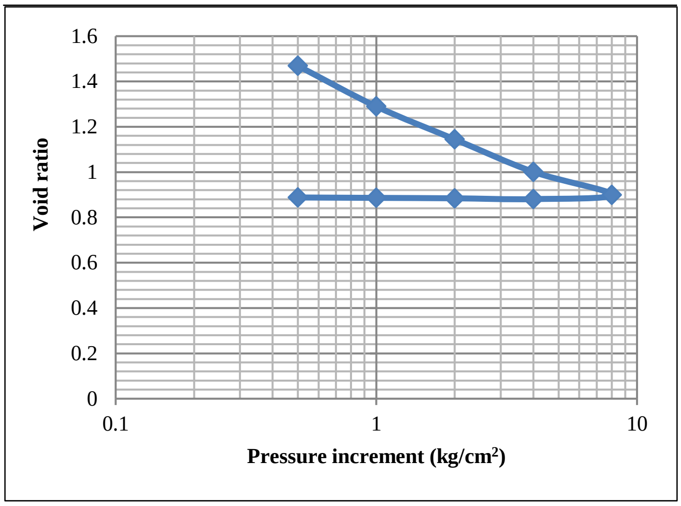

Fig. 3.10 Void ratio versus effective stress curve for peat soil + 12% lime

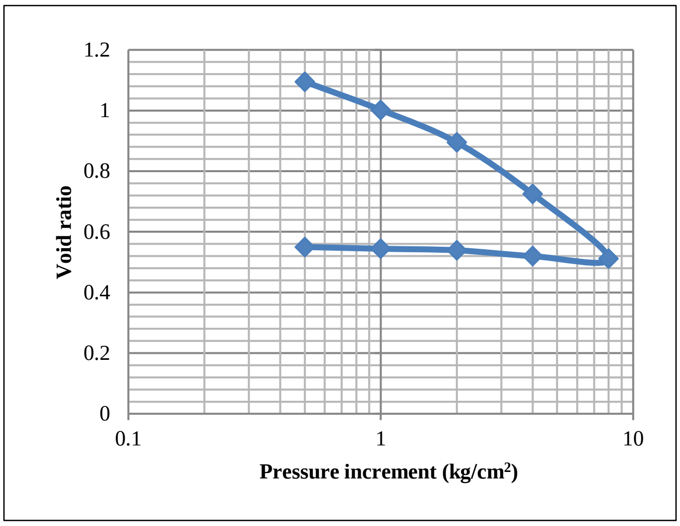

Fig 3.11 Void ratio versus effective stress curve for Peat soil + 20% fly ash

Compression versus square root time curve:

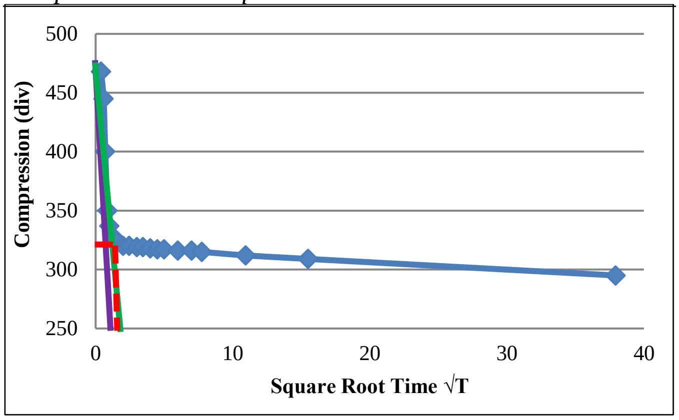

Fig 3.12 Compression versus square root time curve for Peat soil

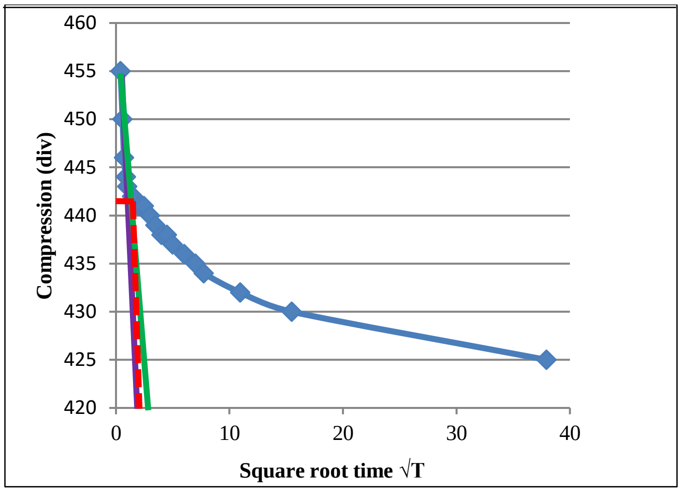

Fig 3.13 Compression versus square root time curve for Peat soil + 12%lime

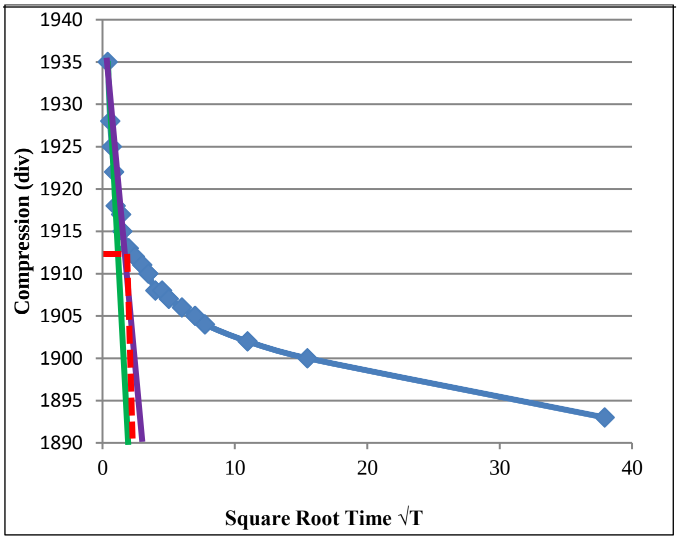

Fig 3.14 Compression versus square root time curve for Peat soil + 20% fly ash

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 12, December-2019

STABILIZED PEAT SOIL

Properties	Peat	Peat + 12% lime	Peat + 20% fly ash
Initial compression (mm)	0.20	0.020	0.08
Primary compression (mm)	0.82	0.076	0.08
Secondary compression (mm)	0.75	0.164	0.22
Compression index C_c	0.61	0.05	0.525
Recompression index C_r	0.072	0.016	0.064
Coefficient of consolidation C_v (cm^2/sec)	3.53×10^{-2}	6.164×10^{-3}	4.824×10^{-3}

The compressibility characteristics such as initial compression, primary compression, secondary compression, compression index and coefficient of consolidation were evaluated for peat soil and peat soil stabilized by 12 % of only lime and 20 % of only fly ash from Figs. 3.9 to 3.14 and as given in Table III. It can be seen from the table that the primary compression and secondary compression are found to decrease for treated peat soil as compared to untreated peat soil. It is observed that the peat soil stabilized by using only lime and only fly ash clearly shows a significant improvement in compressibility characteristics as compared to virgin peat soil.

Secondary compression is important in peat deposits because they exist at high void ratios and exhibit high values of compression. Peat soil deposits accumulate at high void ratios because plant matters that constitute peat particles are light and hold a considerable amount of water. The duration of the primary consolidation for peat soil is relatively short as a result of high initial permeability [6]**.** The compressibility of peat soil is highly influencing on secondary compression as compared to primary compression. Hence, consolidation tests were carried out on untreated and treated peat soil to find the effect of secondary compression. Based on test results, void ratio versus time curves were drawn for untreated and treated peat soil by 12 % lime and 20 % fly ash. Figs. 3.15 to 3.17 show the void ratio versus time curve for untreated and treated peat soil by 12 % lime and 20 % fly ash respectively. The secondary compression characteristics of untreated peat and treated peat soils such as secondary compression index and coefficient of secondary consolidation are evaluated from the Figs. 3.15 to 3.17 and given in Table. IV.

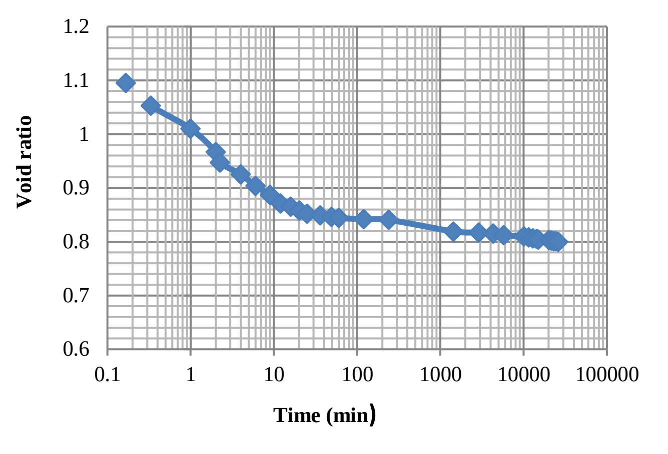

Fig. 3.15 Void ratio versus time curve for virgin peat soil

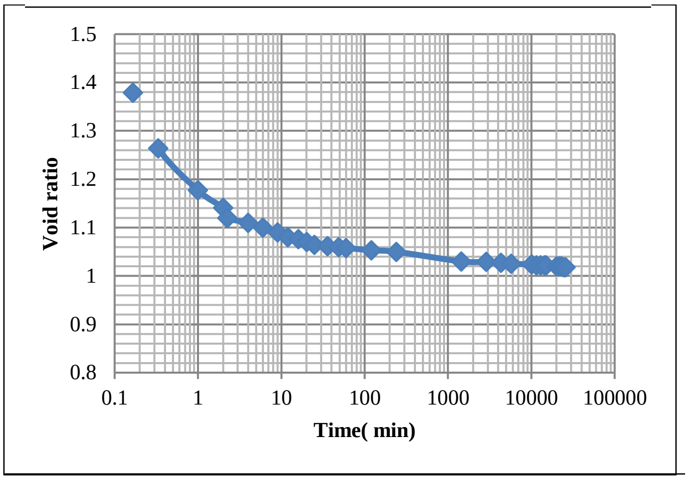

Fig. 3.16 Void ratio versus time curve for peat soil + 12 % lime

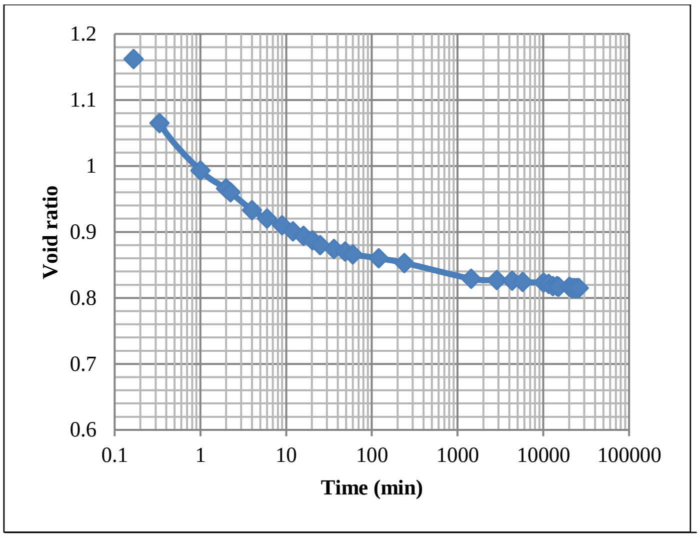

Fig. 3.17 Void ratio versus time curve for peat soil + 20% fly as**h**

TABLE IV. SECONDARY COMPRESSION FOR PEAT SOIL AND STABILIZED PEAT SOIL

Properties	Virgin peat	Peat + 12 % lime	Peat + 20 % fly ash
Coefficient of secondary consolidation (cm^2/sec)	8.0×10^{-2}	4.1×10^{-3}	5.2×10^{-3}
Secondary compression index (C_α)	0.017	0.009	0.011

It can be seen from the Figs. 3.15 to 3.17 and Table IV that the effect of secondary compression is lesser in case of treated peat soil as compared to untreated peat soil. The improvement in secondary compression is better in case of peat soil stabilized with 12 % of only lime as compared to peat soil stabilized with 20 % of only fly ash.

IV. CONCLUSION

The important conclusions as drawn from this study are listed below.

a) Maximum dry density and optimum water content

[1] The MDD of treated peat soil using only fly ash is increasing with increase in percentage of fly ash. OMC found to be increased up to 12 % fly-ash and gradually decrease with increase from 12 % of fly ash.

[2] The MDD of treated peat soil using only lime is increasing with increase in percentage of lime as compared to virgin peat soil and OMC increase till 8 % of lime content.

[3] The MDD of treated peat soil using lime - fly ash mixture is increasing with increase in percentage of fly ash by keeping 12 % of lime content as constant. This trend is common by increasing the fly ash content by up to 20 % and starts decreasing beyond this limit. The OMC decrease with increase in fly ash content up to 20 % by keeping 12 % of lime content as constant.

[4] The MDD of peat soil using lime- fly ash mixture increases with increase in percentage of lime and keeping 20 % fly ash content as constant. OMC is found to decrease with increase in percentage of lime content with 20 % fly ash as constant.

b) Unconfined compressive strength

[1] The UCS value of treated peat soil using only fly ash increases with increase in percentage of fly-ash content. This trend is observed to be significant for the fly ash content increased up to 20 % and starts decreasing beyond this limit.

[2] The UCS value of treated peat soil using only lime increases with increase in percentage of lime content. The increased in strength is found to 3.5 times more for peat soil treated with 12 % lime content.

[3] The UCS value of treated peat soil with 12 % lime and 20 % fly ash mixture is found to 7 times more than the untreated soil.

c) Compressibility Characteristics

[1] Primary compression is found to reduce by 90 % for the peat soil treated with both lime and fly ash.

[2] Secondary compression for the treated peat soil is found to reduce by 47 % for only lime and 35 % for only fly ash as compared to untreated peat soil.

[3] The secondary compression index C_α and Coefficient of secondary consolidation of treated peat soil decreased with increase in both lime and fly ash contents.

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