Enhancement of Soil Properties by using Fly Ash and Metakaolin

D.V.S.Sankara Reddy, K.Kowshik, M.Jugal Kishor, R.Vijaya Durga, V.Pavan Kumar Reddy

Abstract: ***In the presence scenario the economy of a structure is depending upon the type of construction of sub-structure. The load coming from the superstructure is not adequately bear by the soil, it should be strengthened enough by any of soil modification techniques (soil stabilization). In India expansive soil deposits areone of the prime soil deposits in India. The functioning of expansive soils are mainly depends on the existence of Montmorillonite clay mineral, which has an expansive matrix. These types of soil can exhibit high bulging and compressing aspects and have less strength. The problems associated with expansive soil could be revamp by using the admixtures like lime, cement, fly ash, stone dust, quarry dust, rice husk ash etc. So, expansive soils are treated with addition of admixtures is one of the effective soil stabilization methods to strengthen the expansive soils. Numerous researches, all over the earth, are working to develop effective and feasible treatment methods to reduce the problems posed to the construction of paved and unpaved roadson expansive soil sub grade.In this present work laboratory tests were carry out to examine the effectiveness of dissimilar additives are Fly Ash, Metakaolin, Fly Ash + Metakaolin Combinations, in modifying the expansive soil sub grade properties, thereby improving the strength and reducing the swelling and shrinking phenomenon of expansive soil.***

Keywords: Expansive Soil; Pavements; Fly Ash; Metakaolin.

I. INTRODUCTION

Black cotton soils are also named as expansive soils. These soils are expansive in nature.In general These soils mainly existing in western, southern and central parts of India like Maharashtra, Tamilnadu, some regions of Andhra Pradesh, some parts of Gujarat and Madhya Pradesh, Karnataka.In consideration of intense swelling and shrinkage ability, foundation design is very difficult on these soils.Fractures and split-up of pavements, railway and highway embankments, roadways, building foundations, slab-on-grade members, irrigation systems, water lines are to be recognizedas the dangeroustroubles provoked by expansive soils(Gromko, 1974; Wayne et al., 1984; Mowafy and Yousry, 1985; Kehew, 1995). Regrettably the constraints of these soils stand as a hindrance their adaptability in all conditions. So, numerous researches all over the earth, are working to develop effective and feasible treatment methods to reduce the problems posed to the construction of roadson expansive soil sub grade.

The recent technologies evolve for construction of roads is subjected to problems emerge due to varied climate conditions, modifying vehicular pattern, construction materials and sub grade condition.Due to the existence of imperfect sub grade conditions most of the paved and unpaved roads failures can occur.And this type problematic situation can happen in expansive soils sub grade.Metakaolin stabilization is to behelpful for improving the properties of expansive soils and can be used as a structural material (Konstantinos G. Kolovos et.al. 2013).The properties of lateritic soilscould be revamped by adding metakaolin acts as a barricade for the containment of municipal solid waste (Umar et.al., 2015) and also to upgrade the expansive soil properties by adding fly ash, metakaolin, fly ash + metakaolin combinations and it is also used for obstacle, for alternate swelling and shrinking of expansive soil sub grade (Prasada Raju G.V.R et.al., 2016).

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D.V.S. Sankara Reddy, Asst. Professor, Dept. of Civil Eng., Kallam Haranadhareddy Institute of Technology,Guntur, A.P, India.

K. Kowshik , Asst. Professor, Dept. of Civil Eng., Kallam Haranadhareddy Institute of Technology,Guntur, A.P, India.

M. Jugal Kishor, Asst. Professor, Dept. of Civil Eng., Kallam Haranadhareddy Institute of Technology, Guntur, A.P, India.

R. Vijaya Durga, Graduate Student, Dept. of Civil Eng., Kallam Haranadhareddy Institute of Technology, Guntur, A.P, India.

V. Pavan Kumar Reddy, Graduate Student, Dept. of Civil Eng., Kallam Haranadhareddy Institute of Technology, Guntur, A.P, India.

II. MATERIALS USED

A. Black cotton Soil:

The soil used for this investigation is obtained from Thulluru village near Amaravati, Guntur (District). The dried and pulverized material passing through I.S.4.75 mm sieve is taken for the study. The properties of the soil areSpecific gravity - 2.70, Grain size distribution (Sand – 4%, Silt -38%, Clay - 58%), Compaction Parameters (Maximum Dry Density – 14.9Kn/m3, O.M.C. – 28.8%), Atterberg's limits (Liquid limit -72%, Plastic limit - 43%, Plasticity index - 29%, Shrinkage Limit – 13.3%, CBR- soaked – 1.86%. The soil is classified as "CH" as per I.S. Classification (IS 1498:1970) indicating that it is highly compressible clay. It is highly expansive in nature as the Differential Free Swell Index (DFSI) is about 122%.

B. Additives Used:

Fly Ash: Class F fly ash is used. Generally fly ash is released due to the burning of old anthracite and bituminous coal. And it contains little amount of 8-10% lime (CaO) and 50-52% of silica. Usually fly ash have own pozzolanic properties. For the production of cementitious compounds Class F Fly ash required a cementing agent like hydraulic lime,

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Portland cement and quicklime with water, because due to the presence of glassy silica and alumina in fly ash.Sodium silicate (water glass) is a chemical activator so it is added to Class F ash can guide to the generation of a geopolymer.

C. **C.Metakaolin:**

Aluminosilicate material with a dull luster in white color is active thermally which is present in Metakaolin, as calcining kaolin clay is present within the range of temperature 650-8000^{0}C. The Metakaolin has been procured from Jeetmull Jaichandlall Pvt. Ltd., which is present in Chennai, Tamilnadu. The specific gravity and moisture content of Metakaolin are 2.65 & 0.18% respectively. The bulk density of metakaolin is 710 kg/m^3 and value of p^H is 7 which are obtained from the manufacture has physical and chemical features. Metakaolin consists majorly of SiO2, Al2O3, TiO2 and Fe2O3 contributing 53.7 %, 39.2 %, 5.97%, 3.84 %, of the total. In the above components the most generous component is titanium oxide. The amount of SiO2, Al2O3, Fe2O3 should be great than or equal to 70 % for any material, to be used as a pozzolana as per Standard specifications of ASTM (C 618-2012).

III. LABORATORY STUDY

A. **Procedure for Mixing:**

The picked expansive soil from the site is dried and to detach the pebbles and vegetative item if any by hand sorted. It is further dried and crumbled, and sieved through required sieves to abolish gravel fraction if any. The dried and grind soil is preserved in air tight vessels.The soil sample so prepared is then mixed with various Proportions of Fly Ash (Class F) & Metakaolin. The percent of Admixtures content is varied as 3% Fly Ash with 4% Metakaolin, 6% Fly Ash with 8% Metakaolin, 9% Fly Ash with 12% Metakaolin, 12% Fly Ash with 16% Metakaolin. The admixtures content is taken by weight of soil.

B. **Laboratory Tests**

In the laboratory various tests were conducted by using the following standard procedures recommended by I.S codes of practice to investigate the index and engineering properties of the materials used during the research work. The list of diverse assessments conducted with individually and different combinations of enhancers added to the expansive soil. To found the optimum dosages of enhancers corresponding to unconfined compressive strength, compaction parameters, soaked CBR value required for sub grade material (8% CBR as per IRC :37-2012) are presented in Table. 1.

Table I. Different Percentages of admixtures and their optimum dosages of FA, ML, FA + ML.

S. No	Type of Soil	Ad mixtures	Different percent of stabilizing additives (% by weight)	Optimum percentage of different stabilizing additives (% by weight)
1	Expansive soil	Fly Ash	0,3,6,9,12	9
2	Expansive soil	Metakaolin	0,4,8,12,16	12
3	Expansive soil	Fly Ash + Metakaolin	0+0, 2+3, 4+6, 8+6, 6+8	8 FA + 6 ML

IV. GRAPHICAL VARIATION OF RESULTS & DISCUSSIONS

This section describes about the Graphical variation results of Expansive Soil treated with Optimum dosages of stabilization additivesFly Ash, Metakaolin, Fly Ash + Metakaolin Combinations and Discussions.

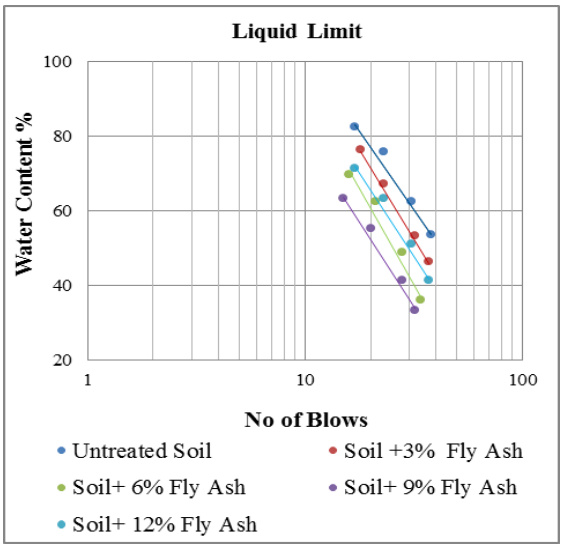

Fig.1 Variations in liquid limit results of expansive soil treated with fly ash.

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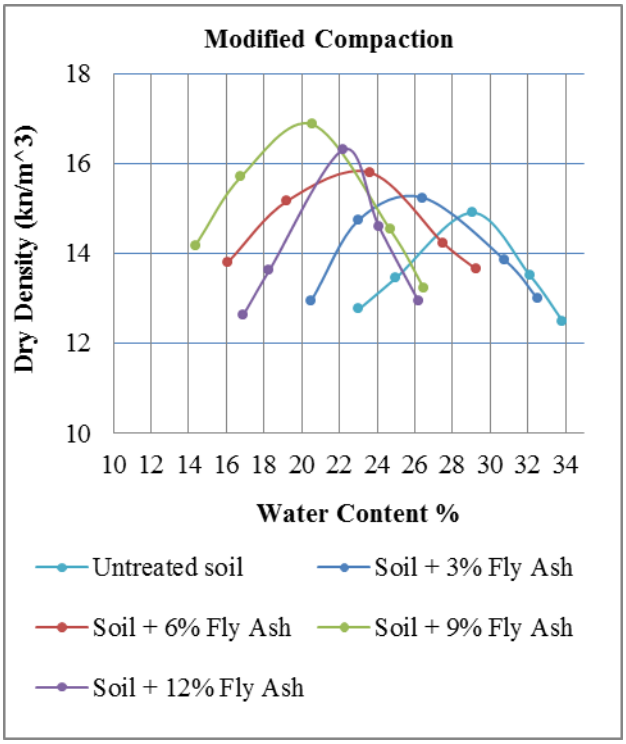

Fig.2 Variations in modified compaction test results of expansive soil treated with fly ash.

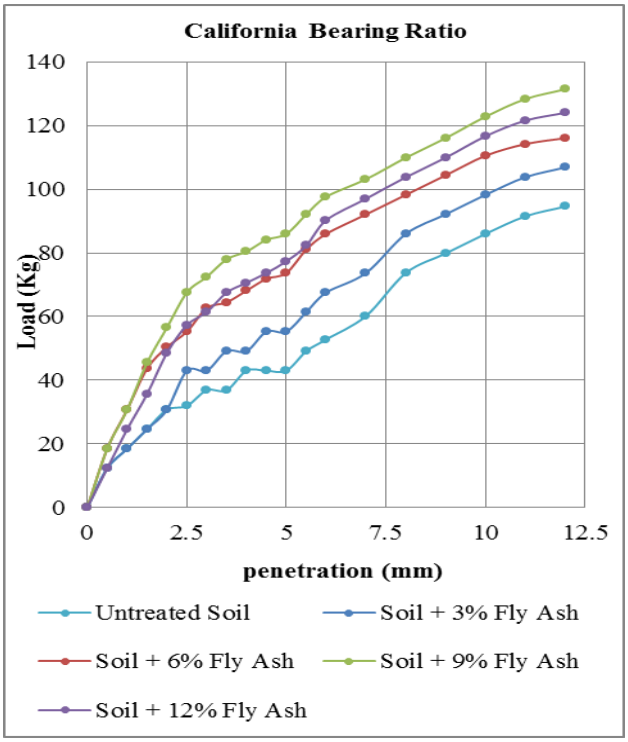

Fig.4 Variations in California bearing ratio test results of expansive soil treated with fly ash.

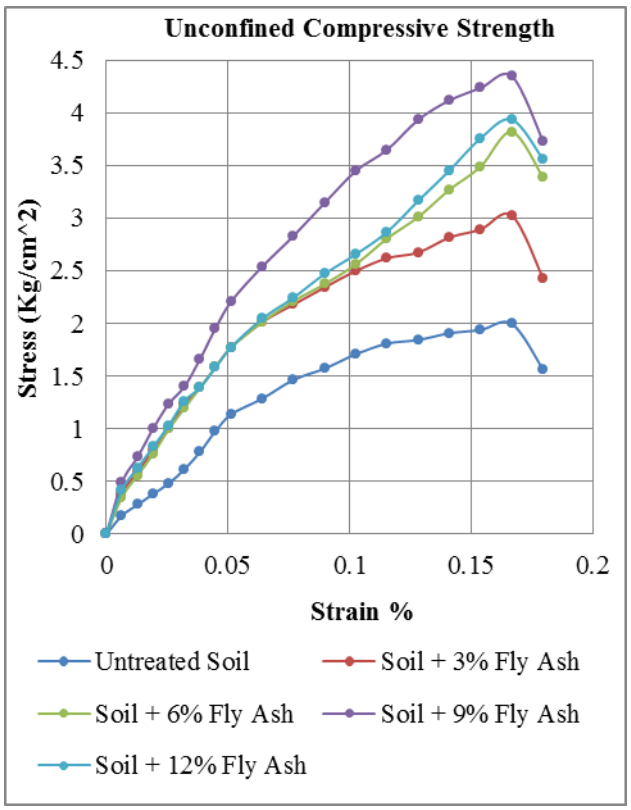

Fig.3 Variations in unconfined compressive strength test results of expansive soil treated fly ash.

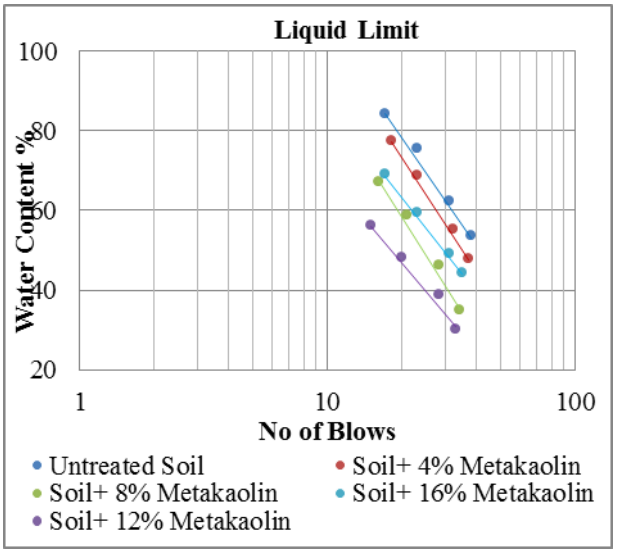

Fig.5 Variations in liquid limit results of expansive soil by the addition of metakaolin.

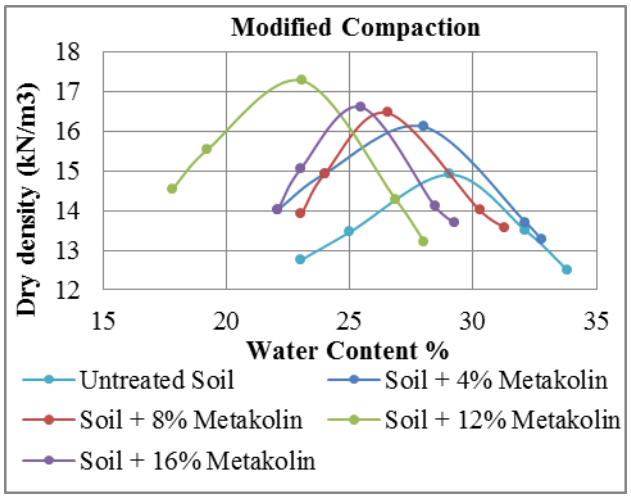

Fig.6 Variations in modified compaction test results of expansive soil by the addition of metakaolin.

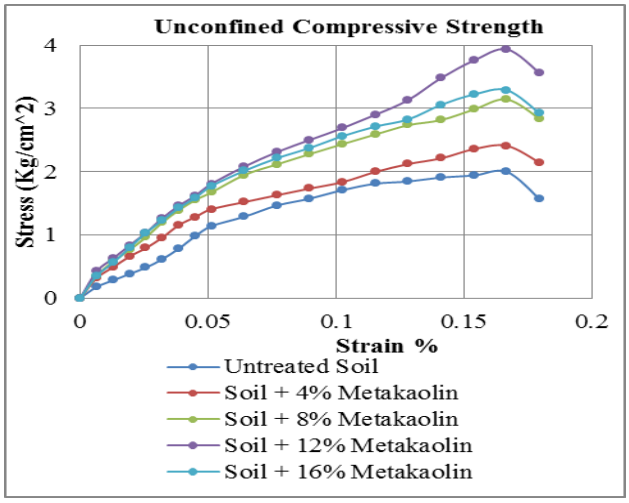

Fig.7 Variations in unconfined compressive strength test results of expansive soil by the addition of metakaolin.

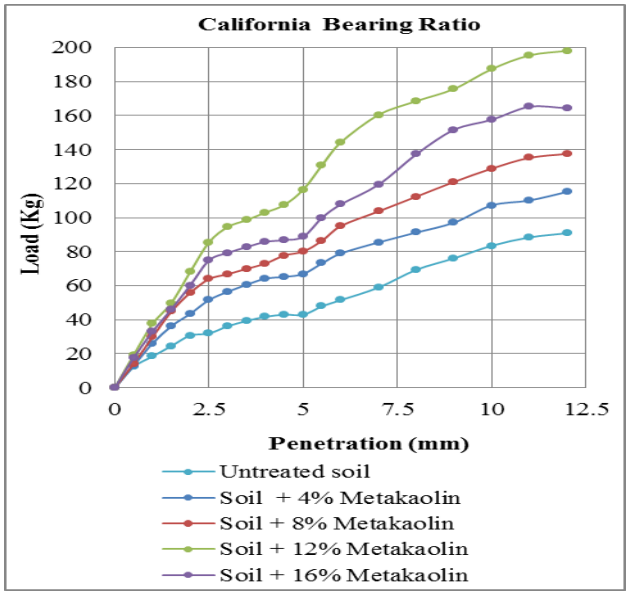

Fig.8 Variations in California bearing ratio test results of expansive soil by the addition of metakaolin.

Soil + Fly Ash + Metakaolin Graphs:

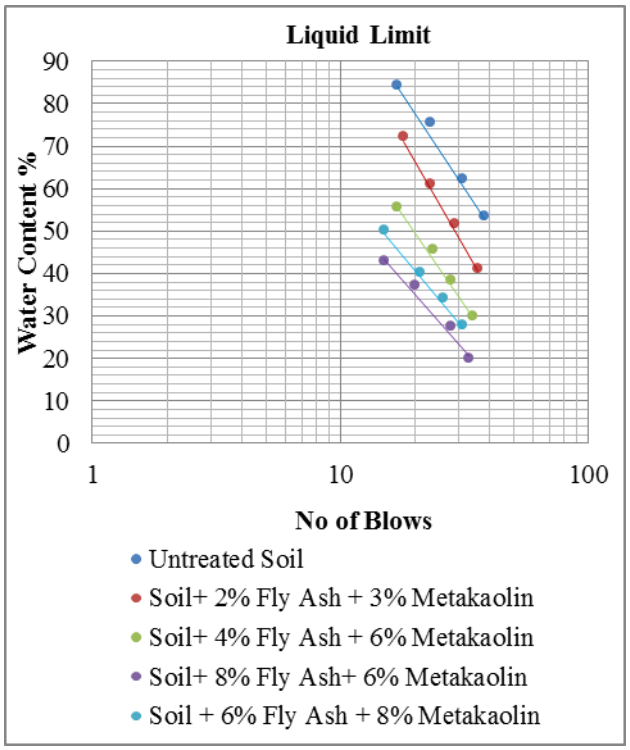

Fig.9 Variations in liquid limit results of expansive soil treated with fly ash + metakaolin admixtures.

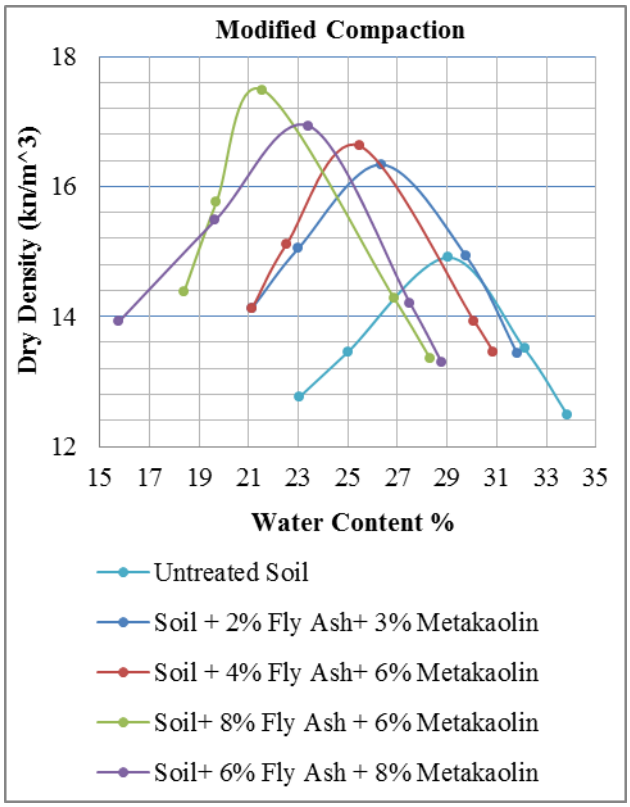

Fig.10 Variations in modified compaction test results of expansive soil treated with fly ash + metakaolin admixtures.

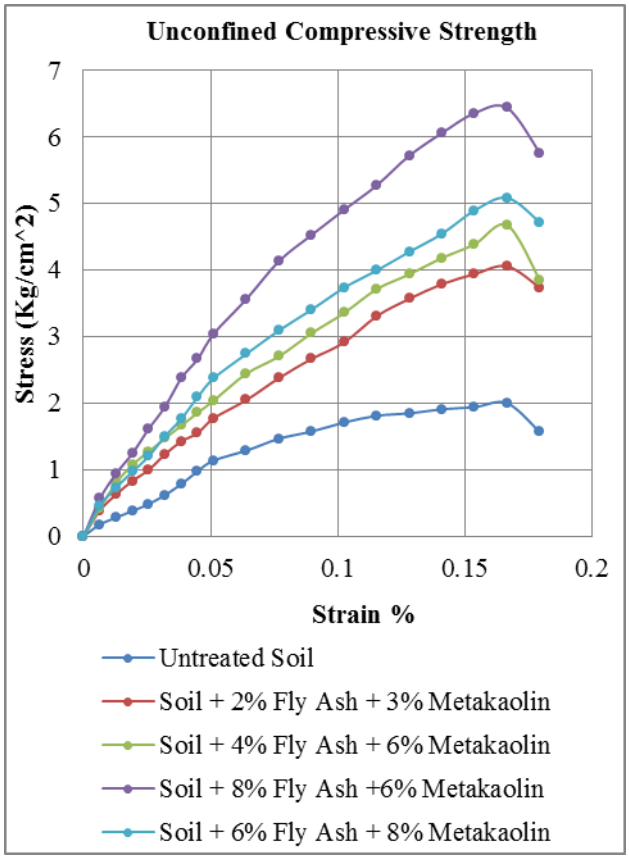

Fig.11 Variations in unconfined compressive strength test results of expansive soil treated with fly ash + metakaolin admixtures.

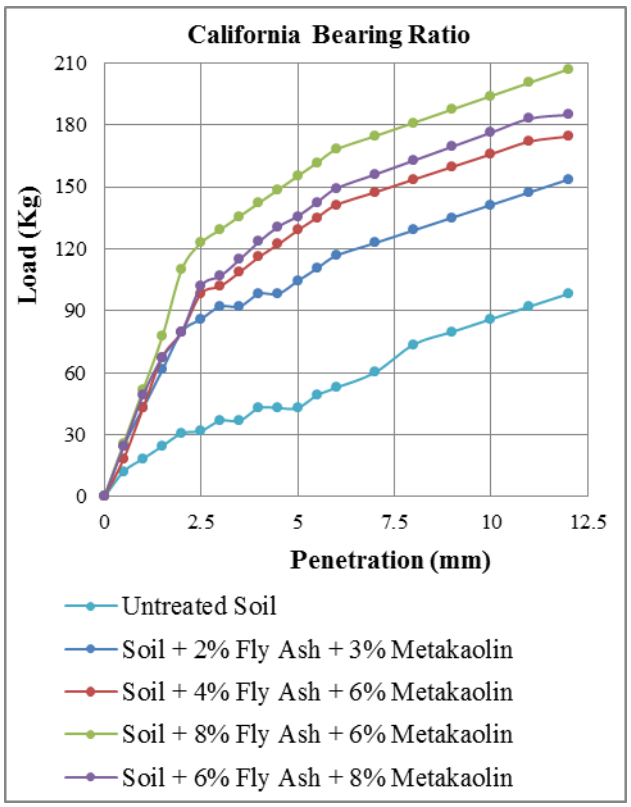

Fig.12 Variations in California bearing ratio test results of expansive soil treated with fly ash + metakaolin admixtures.

IV. DISCUSSIONS

It was observed that liquid limit of the expansive soil got decreased by 40% after adding fly ash to it and it is about 45.27% for metakaolin and for the combined dose of fly ash and metakaolin it is around 60.28%.

The differential free swell index of expansive soil was reduced about 49% from virgin soil by adding fly ash to it, and it is about 61% for metakaolin and for the combined dose of fly ash &metakaolin it is reduced about 63%.

Maximum dry density ofexpansive soil treated with fly ash was observed to be 16.8kN/$m^3$and it is about 17.2kN/m^3 for metakaolin and for the combined dose of fly ash and metakaolin it is around 17.58 kN/m^3.

Optimum moisture content of soil was found gradually decreased by adding fly ash, metakaolin and fly ash + metakaolin combination of admixtures.

The unconfined compressive strength of soil was gradually increased by adding fly ash, metakaolin and combination of fly ash + metakaolin additives.

And also found that Maximum value of soaked CBR is 4.92% by adding fly ash at 2.5mm penetration and for metakaolin 6.24% at 2.5mm penetration and for the combined dose of fly ash and metakaolin it is around8.96% at 2.5mm penetration.

V. CONCLUSIONS

The present study is conducted to inspect the potential use of fly ash, metakaolin, and fly ash + metakaolin combination of admixtures for the improvement of engineering properties of expansive soil. The conclusions are based on the laboratory tests carried out on expansive soil treated with various percentages of fly ash (0%, 3%, 6%, 9%, 12%), metakaolin (0%, 4%, 8%, 12%, 16%) and fly ash + metakaolin combination (0+0, 2+3, 4+6, 8+6, 6+8) of admixtures by % wt. of soil.

The results show that addition of optimum dosage of fly ash (9%), optimum dosage of metakaolin (12%) and optimum dosages of fly ash + metakaolin combination (8% + 6%) of admixtures into black cotton soil could intensify the engineering properties of soil. It was observed that at optimum dosage (8% + 6%) of fly ash + metakaolin added with soil gives maximum reduction in liquid limit is from 72% to 28.6%, differential free swell index is from 122% to 34.16%, and optimum moisture content (from 28.92% to 21.46%).And also there is Optimum values of Maximum dry density (17.58 kN/m^3), unconfined compressive strength (634.8 kN/m^2) and California Bearing Ratio (8.96%) is found. In summary,fly ash + metakaolin combination (8% + 6%) of admixtures added with expansive soiloffers potentiality for long term stabilization of expansive soils.

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