AN EXPERIMENTAL INVESTIGATION ON LOADING BEHAVIOUR OF MODIFIED BLACK COTTON SOIL

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Abstract - *The most deserving aspect of a thesis is its cost, action, ability to withstand damage and time. Soil stability is the principle aspect for the best construction of structures, dams, embankments roads etc. In India, proportion of black cotton soil particles is of great extent. It dominates less shear strength, abnormal enlargement and shrinkage properties. Construction works resting on black cotton soil foundations shows differential settlement and shows continuous distortions in the form of cracking, heave etc. It needs a development in the performance of its service life. Conventional methods for stabilization is mostly a waste of money. So this study aimed an attempt to analyze the influence of ceramic dust and metakaolin on the stability criteria of black cotton soil for foundation beds and pavement structures. It is an eco friendly method. Various dosages of stabilizers were used to evaluate its optimum percentage for the peak improvement in the strength property of soil. Lab tests were conducted on treated soil after 7 days curing to evaluate the enhanced properties. CBR test was done on soil samples after 7, 14 and 28 days curing for the estimation of bearing capacity of soil. Pavement design was done on samples of different CBR value to compare the difference in pavement layer thickness for raw and modified subgrade. Mini plate load test was done on raw and stabilized subgrade for the determination of load carrying capacity of soil. Hence the combined effect of metakaolin and ceramic powder on expansive soil was observed.*

***Key Words*: Metakaolin, Ceramic powder, Black cotton soil, CBR, Mini Plate load test.**

1.INTRODUCTION

Engineers are challenged by different problems related to black cotton soil and adopted different techniques to improve its properties. Majority of the people in India depends on road based transport. Due to high saturation, less degree of compactness, low shear strength and deformation problems, black cotton soil are subjected to volume change and leads to shrinkage on dry condition and swelling on wet condition. These type of soil are generally not suitable for the construction of pavement and foundation soil beds due to insufficient strength. These deposits needs a modification before the application of any external load. In order to improve the properties of soil, various methods like chemical stabilization, reinforcement techniques etc to be used.

Maintenance and replacement of pavement consumes a large portion of the budgets of transportation departments in every country. Modern pavements are expected to provide high level of safety and comfort. Pavements are commonly designed using a combination of mechanistic and empirical approaches. It involves selection of the appropriate soil and pavement parameters and then calculating layer thickness for the sub base, base and surface layers. In any method, strength parameter is used to describe the subgrade strength. In order to reduce these problems, different methods are used to minimize the variability in subgrade characteristics. In this study metakaolin and ceramic powder are used to improve the geotechnical properties of subgrade of a flexible pavement structure which reduces uneven settlement. To know the influence of stabilizers used, it undergoes various laboratory experiments to obtain optimum mix. Mini plate load test and pavement design were done on modified soil properties which is the basic factor for road constructions.

2. LITERATURE REVIEW

Venkateswarlu Dumpa, Rajesh Vipparty, Anjan Kumar Mantripragada, Prasada Raju G. V. R. [1] conducted an experimental study on evaluating the strength characteristics of lime and metakaolin on expansive soil. Optimum values for lime and metakaolin was obtained from laboratory experiments. Cyclic plate test was conducted on untreated and treated subgrade. The load carrying capacity of treated subgrade is high compared to untreated one.

J.T. Shahul, S. Patel and A. Senapati [2] studied the effect of Copper Slag, Fly Ash–Dolime Mix and its utilization in the base Course of Flexible Pavements. Analysis of pavement structure laid on treated soil was conducted by Plaxis 2D software. Deflection on each layers were determined by Mohr- Coulomb model Plaxis 2D.

S.Dandin, P.Shinde, S.Rathod3, S.Ostwal, A.Borade, M.Chincholka [3] conducted a study on expansive soil. Stabilization of expansive soil was done to obtain enhanced geotechnical properties on treating it with RBI grade 81.

Mahmoud D. Ahmed, Nisreen A. Hamza [4] studied the effect of metakaolin on geotechnical properties of expansive soil. Soil becomes more coarser size due to pozzolanic reaction between soil and metakaolin. Cohesion of soil was found to be increased.

Chen James A, Idusuyi [5] studied the effect of waste ceramic dust on index and engineering properties of shrink-swell soils. MDD, UCS value and soaked CBR value was found to be increased. OMC, Free swell and Swelling Pressure was found to be decreased.

Devendra Kumar Choudhary, Dr. Y. P Joshi [6] conducted a detailed Study of CBR Method for Flexible Pavement Design. Comparitive study of the behaviour of clayey silt and red soil were conducted and pavement design were done based on CBR results.

J N Mandal [7] conducted a study on geogrid reinforced pavement. It shows less deformation as the axial stiffness of geogrid increases. Vertical surface deformation on the surface of pavement structure with respect to variation in the pavement thickness at same loading condition was to be observed by plaxis 2D.

Tarekegn Kumela [8] conducted an analysis of stress strain and deflection of flexible pavements using Finite Element Method where subgrade modulus is the key element that controls the excess vertical surface deflections in flexible pavement. It was found that vertical deflection reduces as the modulus increases.

3. MATERIALS

The materials selected for the study are black cotton soil, metakaolin and ceramic powder.

3.1 Black cotton soil

Soil for the experiment was collected at a depth of 0.5m from ground level at Chittor near Paracherukottu Velli road. Field density and water content obtained were 1.6g/cc and 31%.

Fig -1: Black cotton soil

3.2 Metakaolin

Metakaolin is a dehydroxylated form of kaolinite clay. It was one of the stabilizer used in the thesis for soil stabilization. It was collected from English Indian Clay Limited, Thonnakkal near Attingal. Its potential use is to act as a bulk filler. It is a pozzolanic material formed through the process of calcination of kaolinite clay at 700 to 800^{0}c. It is white in colour and size is in between 2 to 10 micrometer. It is obtained as powdered form having specific surface area of 10 to 25 m^2/g. Specific gravity was 2.5. Liquid limit, plastic limit and plasticity index were 55%, 27% and 28%.

Fig-2 . Metakaolin

Table 1. Composition of Metakaolin

Silica	52 – 55%
Alumina	40 – 43%
Ferric oxide	2 - 2.5%
Calcium oxide	1- 3 %

3.3. Ceramic Powder

Ceramic is an inorganic compound has high hardness, modulus of elascity, toughness, compressive strength. Potential use is to widening the black cotton soil. Hence soil become coarser and good to use as a subgrade for pavement construction. It was collected from ceramic industry at kollam. It is waste product from the industry which is white grey in colour. The specific gravity was found be 2.65. Maximum dry density and OMC were obtained as 1.8g/cc and 25%. Liquid limit, plastic limit and plasticity index were 37%, 18% and 19%.

Fig-3. Ceramic powder

To study the influence of stabilizers used, the collected sample is properly air dried for conducting the laboratory tests. The properties of expansive soil is determined as per IS specifications.

3.1.1 Tests on Black cotton soil

The tests conducted on soil are as follows:

1. Specific gravity test
2. Grain size analysis

3. Proctor test
4. Atterberg limits test
5. Free swell index test
6. Triaxial test
7. Unconfined compressive strength test
8. CBR test

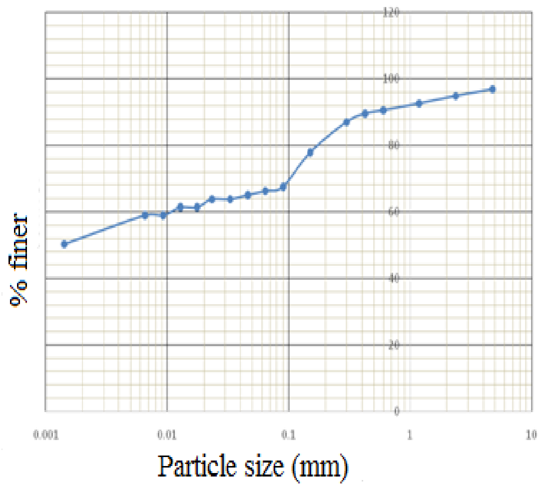

Chart -1: Particle size distribution curve for soil

Table -2: Properties of untreated black cotton soil

Properties	Values
Specific gravity	2.3
Dry density	1.52g/cc
Optimum water content	22%
Angle of internal friction	9 °
Cohesion	0.4 kg/cm^2
Shear strength	0.48 kg/cm^2
Swell index	104%
UCC	10.35 kN/m^2
Liquid limit	66%
Plastic limit	25%
Plasticity index	41%
Shrinkage limit	17.6%
Volumetric shrinkage	162.19%
CBR	2.97%
Subgrade modulus	29.7Mpa

4. METHODOLOGY

In this study the effect of metakaolin and ceramic powder on black cotton soil was obtained from laboratory experiments. Firstly samples collection was done.Through XRD quantative analysis, soil was analysed as black cotton soil due to the presence of high percentage of montmorillonite. Hydrometer analysis was done to determine the amount of clay content on it. All geotechnical properties of virgin soil sample were determined through laboratory experiments. In order to improve the dynamic properties of soil sample, stabilizers were used. Through proctor test optimum values of stabilizers used were obtained. Laboratory experiments were conducted to determine the enhancing properties of stabilized black cotton soil after 7 days of curing. Through CBR value the pavement layer thickness were obtained for treated and untreated one. Load carrying capacity of subgrade was obtained from mini plate test.

Fig -4: Soil filled in the Mini Plate load tank

Tank was modeled for a dimension of 29 cm x 29cm x29 cm. The untreated soil is filled in the tank in optimum density condition upto a depth of 25 cm. The loading plate of 100 mm x 100 mm size are placed on soil and tested by using loading mechanism. Thickness of plate is 10mm. The test results of both treated and untreated conditions are compared.

4.1 Preparation of soil bed

The collected soil sample was dried completely. Based on the result of standard proctor test, the tank was filled in optimum dry density (1.52 g/cc)and water content (22%). The soil was filled with 5 layers with 25 blows inorder to achieve required density. It was filled upto a height of 25 cm. For treated soil, three tests were conducted. Firstly for soil with optimum mix of metakaolin and ceramic powder after 7, 14 and 28 days curing. It is filled in optimum dry density (1.72g/cc) and water content (19%).

5. EXPERIMENTAL TEST

In order to apply the load, place the model set up on the triaxial machine. A handle is provided to apply load manually by rotating it at a constant loading rate is distributed through the loading plate. Proving ring is attached to the plate and displacement corresponding to each load is noted by means of digital dial setup. So the maximum displacement value measured here is 20 mm.

Fig -5: Loading arrangement in Triaxial apparatus

6. RESULTS AND DISCUSSIONS

Optimum values of stabilizers used in soil were obtained as 5% metakaolin and 2% ceramic powder after 7 days of curing. The improved geotechnical properties of stabilised black cotton soil were determined as shown in Table.3. Based on determination of CBR values for untreated and treated soil, pavement design was done. Reduction in the pavement layer thickness was obtained. Mini Plate load test was tested for the above described conditions and the intensity of load versus displacement curves are plotted. From this it is confirm that for all loading cases, the modified soil gives maximum loading capacity as compared to that of untreated one.

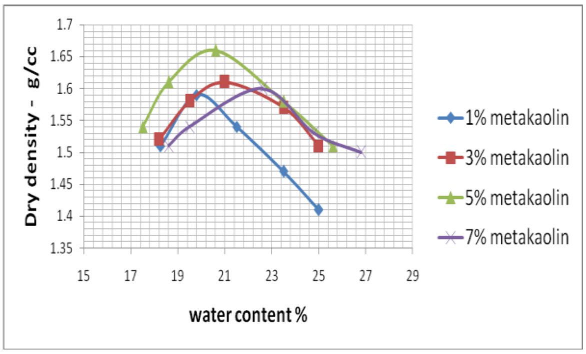

Chart.2: Compaction curve for optimum value of metakaolin

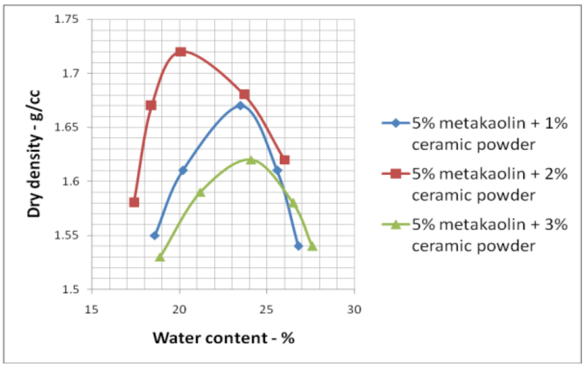

Chart.3: Compaction curve for optimum value of ceramic powder

Table:3 Properties of treated black cotton soil

Properties	Values
Dry density	1.72g/cc
Optimum water content	19%
Angle of internal friction	16°
Cohesion	0.1 kg/cm²
Shear strength	0.89 kg/cm²
Swell index	66%
UCC	34.4 kN/m²
Liquid limit	54%
Plastic limit	21%
Plasticity index	33%
CBR	6.4%
Subgrade modulus	57.5Mpa

6.1 CBR Test and Pavement Design

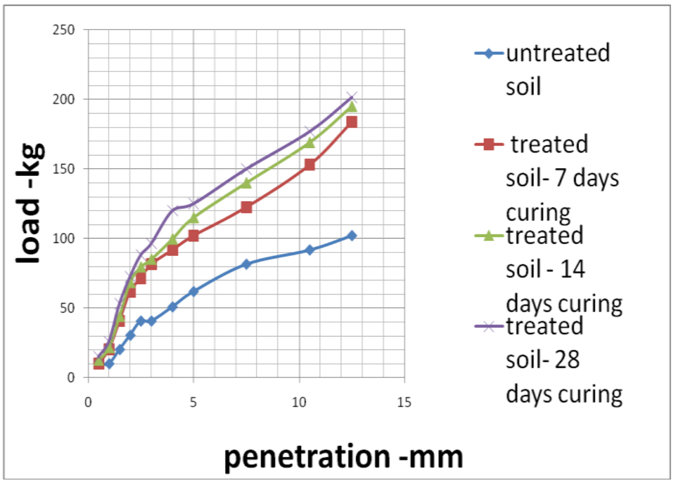

Chart -4: Load penetration curve

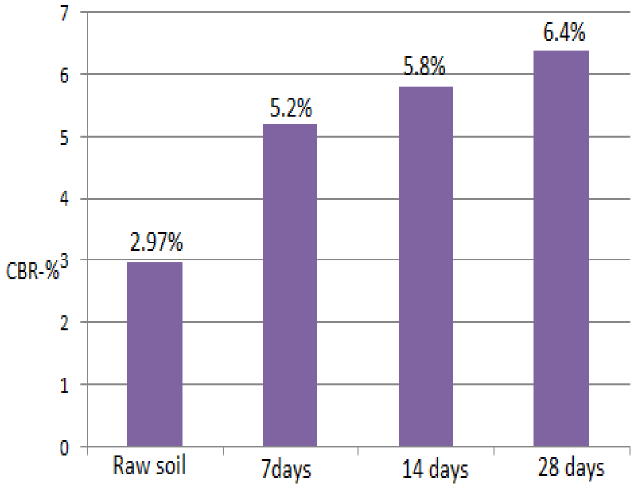

Chart.5: Variation of CBR value

CBR test was done on black cotton soil after 7, 14 and 28 days of curing. Results obtained as 2.97% for raw soil, 5.2%

for modified one after 7 days curing, 5.8% after 14 days curing and 6.4% after 28 days curing. Based on CBR results, the thickness of flexible pavement layers laid on untreated and treated subgrade was obtained. Thickness for subbase, base and surface course for untreated subgrade are 382mm, 250mm and 130mm. Thickness of subbase, base and surface course for treated subgrade are 292mm, 250mm and 109mm.

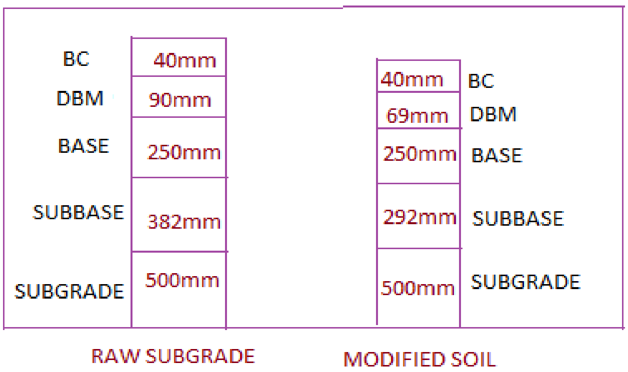

Fig.4: Variation in pavement layer thickness

6.2. Loading behaviour of modified black cotton soil

Here three tests were conducted for the determination of loading capacity of expansive soil. First test was conducted on untreated soil, second was done on 5% metakaolin+2% ceramic powder mix soil after 7, 14 and 28 days curing. In all three cases, load intensity up to 20 mm is measured. The subgrade failure takes on pavement structure when its deformation exceeds 20mm. Hence the load intensity for untreated soil on 20mm displacement was obtained as 7.5 kN. For 5% metakaolin+2% ceramic powder mix soil have load intensity of 11.5 kN after 7 days, 12.4 kN after 14 days and 13.2 kN after 28 days.

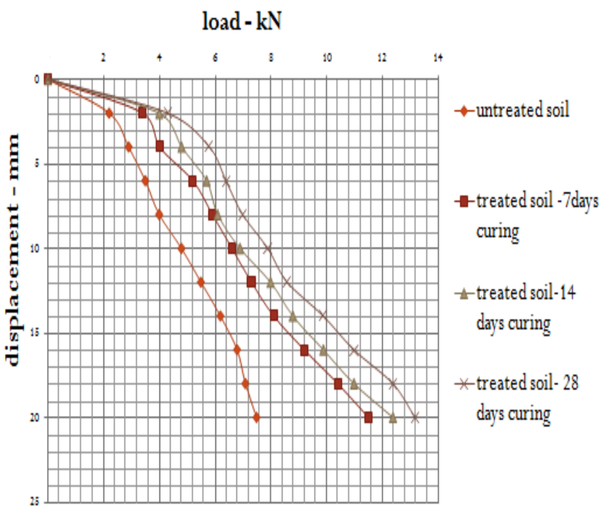

Chart-6: Load Displacement Curve

7. CONCLUSIONS

- Dry density was found to be increased from 1.52g/cc to 1.72 g/cc.
- Plasticity index was found to be decreased from 41% to 33%.
- Unconfined compressive strength was increased from 10.35kN/m^2 to 34.4/m^2 .
- Shear strength was increased from 0.48 kg/cm^2 to 0.89 kg/cm^2 .
- Swell index was decreased from 104% to 66%.
- Soaked CBR value was increased from 2.97% to 6.4%, hence the bearing capacity was found to be improved.
- Pavement layer thickness was reduced from 762mm to 651mm which makes the construction process economical.
- Load carrying capacity of soil is higher in treated as compared to untreated one.
- Settlement of treated soil is less as compared to raw soil.

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