STABILIZATION OF CLAYEY SOIL USING LIME AND CEMENT

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ABSTRACT: Expansive soils are found in India in large tracts. These soils continue to pose problems to engineers for safety of any structure or pavement; these problems are due to volume changes that take place in the soil with update of water during monsoon and evaporation during summer. Improvement of poor sub grades is inevitable to prevent premature pavement failures. As the quality of a poor sub grade layer is improved, its ability to distribute the load over a greater area is increased. Soil layer’s strength can be improved by using additives. Generally stabilization is done to improve poor sub grades by the process of blending or mixing additives. Several methods have been suggested to control this problem. The most commonly used method is addition of stabilizing agents, such as lime, cement and fly ash to the expansive soils. In the present study lime and cement were used for the stabilization of an expansive soil. In the present investigation expansive soil has been tested in the laboratory by adding in percentages ranging from 2-12% of cement and 2-10% of lime and for the combination of cement and lime, the lime was added in percentages ranging from 2-8% for 4% cement content. In this, Compaction, CBR, Unconfined Compression strength parameters with & without curing are studied. It is shown that with adding cement and lime the shrinkage and plasticity are treated. Maximum dry density increased marginally with the increase of cement & lime content up to 8% and 6% respectively and correspondingly there is reduction in OMC. CBR values are increased in accordance with the increase of the maximum dry density, and shear strength values are increased continuously with the increase of admixture cement. And for the combination of cement and lime, MDD occurred at 4% lime for 4% cement. The stabilization with lime is very promising compared to the cement stabilization.

INTRODUCTION

Expansive soils are colloidal soils containing particles less than 2 micron size, the traction varying between 50 and 70 percent. They are formed as a result of weathering of traps and basalts. The liquid limit and plasticity index values range from 40 to 100% and 20 to 26 respectively. In exceptional cases, the liquid limit might exceed 100%. In India one fifth to one sixth part of surface deposits consists of expansive soils, these are called as Black cotton soils in India. BC soil deposits in India are a boon to farmers but are problematic to civil engineers. Civil engineering structures experiences large-scale damage due to heaving accompanied by loss of strength of these soils during rainy season and shrinkage during summer. All clays expand and shrink with the entry and exit of water, yet some are called the expansive type and need special precautions when
used under roads and buildings. The black cotton soils of India have predominance of montmorillonite clay mineral. They are formed as a result of weathering of traps and basalts. Natural deposits of BC soils in the field are characterized by general pattern of cracks, especially during the dry season of the year. Under buildings founded on BC soil, the heaving is observed to be uneven, being more under the central portion than on the periphery. The differential heave is injurious to the structure. The nature and amount of clay mineral present mainly influences expansive properties of particular clay. Amongst the clay minerals, three main types - Montmorillonite, Illite and Kaolinite impart the expansive properties to clay in the descending order. Therefore, it is natural that design and construction engineers are apprehensive of using black cotton soils as a construction material for earth dams, embankments, and roadwork, under buildings. The liquid limit and plasticity index values range from 40 to 100% and 20 to 26 respectively. In exceptional cases, the liquid limit might exceed 100%. The thickness of B.C soils may even extend up to maximum depth of 20m. But the effect of seasonal moisture variations brings about volume changes up to a depth of about 1.5-2 m in below G.L. (Katti-1979). The problems with these expansive soils can be reduced by using soil stabilization techniques. Soil stabilization is a technique employed to modify the soil properties, and for improving the engineering performance. Stabilization is being used for a variety of engineering works, the most common application being in the construction of roads, embankments, airfields and pavements. The main objective is to increase the strength or stability of soil and to reduce the cost of construction by making use of the locally available construction materials. The scope of soil stabilization is very wide. Methods of stabilization may be grouped under two main types: (i) modification of a soil property of the existing soil without using any admixture and (ii) modification of the properties with the help of admixture. The examples of the first type are compaction and drainage, which improve the inherent shear strength of soil. The examples of the second type are stabilization with admixtures like cement, lime, bitumen, fly ash and chemicals. Deep soil deposits are stabilized by electrical methods, grouting, freezing etc. The degree of stabilization required depends on the type and use of soil and importance of the structure may be used alone built on it. The use of lime, cement and bitumen has become common as stabilizing agent.

TESTING PROGRAMME

Following tests are conducted on stabilized soil.

(i) Modified proctor's test.

(ii) CBR test

(iii) Unconfined Compression test.

(i) Compaction

Compaction tests were conducted on Admixture stabilized soil using lime and cement as Admixtures. For the Admixture stabilization of lime, it was mixed in percentages Bing from 2% to 10%. For the Cement stabilization, it was mixed in percentages ranging m 2% to 12%. And for the Cement-lime stabilization Lime was added in percentages ranging from 2% to 8% by keeping Cement content constantly at 4%. After mixing the soil with certain percentage of Admixture, Compaction tests were performed according to Indian standard specification IS: 2720 (Part VII -1980). Compaction curves were in shown in figures 3.1 and 4.1-4.3. The results obtained in the Compaction tests were reported in Tables 4.1-4.3.

(ii) California Bearing Ratio (CBR)
CBR is defined as the ratio of the test load required to force a cylindrical plunger of 50mm diameter into a soil mass at the rate of 1.25mm per minute to the load required for corresponding penetration of the plunger into a standard sample of crushed stone. CBR (\%) = \frac{\text{Test load}}{\text{Standard load}} \times 100

CBR value is determined corresponding to both 2.5mm and 5mm penetration and the greater of the value is used for design purposes. The cylindrical specimens have been compacted in the CBR mould at Proctor's maximum dry density and optimum water content.

CBR test is performed according to IS: 2720 (Part —XVI) - 1987. The MDD and OMC values for the CBR tests were taken from the results of compaction tests corresponding to respective percentage of Admixture content. A smooth curve has been drawn between the penetration of the plunger as abscissa and the load on the plunger as ordinate. The test loads corresponding to 2.5 mm and 5 mm penetration have been read from the curve and the CBR values have been calculated. If CBR value corresponding to penetration of 5mm exceeds that of 2.5 mm, the test is repeated. This test is repeated for different percentages of cement, lime stabilized soils. Also, soaked CBR values were obtained by soaking the specimen in water before conducting the test mentioned above. CBR curves for both unsoaked and soaked condition for different admixtures were shown in figures 3.2 and 4.4-4.6. The results obtained from the CBR tests were reported in Tables 4.4-4.6.

(iii) Unconfined Compression Test

The maximum load can be transmitted to the sub-soil by a foundation depends upon the resistance of the underlying soil or rock to shearing deformation or compressibility. Therefore it is of prime importance to investigate the factors that control the shear strength of these materials. The shearing strength is commonly investigated by means of compression tests in which an axial load applied to the specimen and increased until failure occurs. The use of compression tests to investigate the shearing strength of material depends upon the fact failure in such tests takes place by shear on one or more inclined planes and that it is possible to compute the normal pressure and shearing stress on such a plane at the instant of failure. The specimen may or may not be subjected to a lateral pressure during the test. When it is not, the test is known as Unconfined Compression test. Unconfined compression test is conducted according to IS: 2720 (Part- X) - 1973. The samples were prepared by taking the MDD and OMC values obtained from the compaction tests.

Preparation of soil specimen

In order to prepare the sample, first the dry mix was prepared uniformly taking the predetermined amount of soil and lime or cement. The water added to the mix was kept with corresponding to OMC of the respective mix. Before compaction, the mix was kept with a cover for few hours to get the uniform distribution of moisture. A calculated weight of mix was, and then compacted in a split spoon sampler as a mould (dia.38mm.arld 76r.rn) in three layers in such a manner to get the MDD of the mix. The procedure was basically a trial and error method, but MDD was checked properly by taking the weight of the prepared sample and the volume of the mould. The sample was then subjected to compression device at a strain rate of 0.76 mm/min.curing of sample was done in dessicator at room temperature for specified days. For each parameter (i.e.
compression variable and curing time) three tests were performed. The average of two close values has been reported as the compressive strength of the particular mix.

RESULTS AND DISCUSSIONS

The experimental investigations were conducted as mentioned to assess the compaction characteristics, shear strength parameters and CBR values. The shear parameters were determined by unconfined compression method. The compaction tests were conducted to obtain maximum dry density and optimum moisture contents for various percentages of admixtures. The CBR tests were conducted to study load verses penetration characteristics of soil — admixture. The strength characteristics of soil-admixture are generally measured by means of shear strength or CBR values. The optimum admixture content for maximum strength is not a stable value, but varies with the amount of clay, type of clay mineral present; curing period.

EFFECT OF COMPACTION

Fig.1.1 shows how the modified Proctor's compaction curves of soil with variation of lime content ranging from 2% to 10%. It is noticed that with an increase in percentage of lime the curves shifted to left side upwards. This means that an increase of maximum dry density and reduction in optimum moisture content up to lime content of 6% and thereafter MDD decreases and OMC increases.

Fig. 1.2: variation of OMC with lime content

Fig. 1.3 shows Proctor's compaction curves of soil with variation of cement content ranging from 2% to 12%. It is noticed that with an increase in percentage of cement content the curves shifted to left side upwards. This means that an increase of maximum dry density and reduction in optimum moisture content up to 8% of cement, and there after MDD decreases and OMC increases.

Fig. 1.4 plots the corresponding graph for OMC.

Figs.1.5 and 1.6 shows Proctor's compaction curves of soil with variation of lime content ranging from 2% to 8% by keeping cement content constantly at 4%. It is noticed increase in percentage of lime up to 4% MDD increases and there after it decreases.

Fig.1.5 and Fig. 1.6 are the plots of MDD and OMC with the variation of admixture content respectively.

Fig. 1.1: variation of MDD with lime content

Fig. 1.2: variation of OMC with lime content
EFFECT OF CBR VALUES

The CBR values are determined by conducting CBR tests for various percentages of lime. The variation of CBR values with lime content is plotted in Figs 1.7 and 1.8 both for unsoaked and soaked conditions respectively. It is seen that the CBR values are increased in accordance with the increase of MDD and decrease of OMC.

The variation of CBR values with cement content is plotted in Figs 1.9 and 1.10 both for unsoaked and soaked conditions respectively. It is seen that the CBR values are increased in accordance with the increase of MDD and decrease of OMC.

The variation of CBR values with 4% cement content and different percentages of lime are shown in Figs. 1.11 and 1.12 for both unsoaked and soaked conditions. The results shown that CBR values increased for both soaked and unsoaked condition up to 4% of lime and afterwards it decreases.

The CBR values are increased in accordance with the increase of the dry density for all types of admixture stabilization. And the CBR Soaked values...
are more than CBR Unsoaked values for all types of stabilization; this may be due to cementacious action of cement and lime.

It is concluded that stabilization alone does not seem to alter the strength properties of the soil. There is a slight modification of properties with regard to compaction.

Fig.1.7: variation of CBR unsoaked value with lime content

Fig.1.8: variation of CBR soaked value with lime content

Fig.1.9: variation of CBR unsoaked value with cement content

Fig.1.10: variation of CBR soaked value with cement content

Fig.1.11: variation of CBR unsoaked value with 4% cement content and lime content (%)
Fig. 1.12: Variation of CBR soaked value with 4% cement content and lime content (%)

**EFFECT OF SHEAR STRENGTH**

Fig. 1.13 is a plot of unconfined compression test for natural soil before and after 28 days curing. Figs. 1.14 and 1.15 are plots of lime as an admixture before and after 28 days curing. Figs. 1.16 and 1.17 are plots of unconfined compression test for soil with cement as admixture before and after 28 days curing. Figs. 1.18 and 1.19 are plots of unconfined compression test for soil with 4% cement and different percentages of lime before and after 28 days curing. Figs. 1.20 to 1.25 are the plots of shear strength variation with percentage of admixture respectively for lime, cement and lime with 4% cement.

The results shown that shear strength is increasing continuously with increase of admixture content. The increase of shear strength is due to the increase of cohesion or angle of internal friction.

The increase in cohesion may be due to the formation of cementitious products as a result of pozzolonic action or due to the formation of agglomeration and cementation bonds, which is physico-chemical phenomenon. The increase of angle of internal friction could be attributed to the flocculation of clay particles thus making soil coarser.

Fig. 1.13: Variation of unconfined compression for natural soil before and after 28 days curing

Fig. 1.14: Variation of unconfined compression by adding different percentages of lime

Fig. 1.15: Variation of unconfined compression for soil after 28 days curing with different percentages of lime

Fig. 1.16: Variation of CBR soaked value with 4% cement content and lime content (%).
Fig. 1.16: variation of unconfined compression by adding different percentages of cement

Fig. 1.17: variation of unconfined compression for soil after 28 days curing with different percentages of cement

Fig. 1.18: variation of unconfined compression for 4% cement adding with different percentages of lime

Fig. 1.19: variation of unconfined compression for soil after 28 days curing with 4% cement and different percentages of cement

Fig. 1.20: variation of cohesion by adding different percentages of cement

Fig. 1.21: variation of angle og internal friction values by adding different percentages of cement
CONCLUSIONS

The following conclusions can be drawn from experimental study.

**Compaction parameters:**

1. Lime stabilization has shown the maximum value of MDD and minimum value of OMC at 6% of lime content.

2. Cement stabilization has shown the maximum value of MDD and minimum value of OMC at 8% of cement content.

3. Cement-Lime stabilization has shown the maximum value of MDD and minimum value of OMC at 4% of lime content for 4% cement content.

**CBR values:**

1. Maximum CBR values for both Unsoaked and soaked condition are 31.11% & 36.86% respectively occurred at 6% of lime content for the lime stabilization.

2. Maximum CBR values for both Unsoaked and soaked condition are 28.93% & 32.26% respectively occurred at
8% of cement content for the Cement stabilization.

3. Maximum CBR values for both Unsoaked and soaked condition are 29.81% & 33.43% respectively occurred at 4% of lime content for the Cement-lime stabilization.

Shear strength parameters:

Shear strength values are increases continuously with the increase of Admixture content.

1. For the lime stabilization maximum value of shear strength occurred at 6% of lime content.

2. For the Cement stabilization maximum value of shear strength occurred at 8% of cement content.

3. For the Cement- lime stabilization maximum value of shear strength occurred at 4% of lime content for 4% of cement content.

It appears that the stabilization of clayey soils with cement itself is not effective and it also shows that lime-cement stabilization is also not effective compared to the lime stabilization.

Effect of curing on the shear strength:

1. Based on the plot of % substitution (vs.) shear parameters for with out and with 28 days curing, it is found that, in general the samples have exhibited phenomenal increase in both Cohesion (C) & angle of sharing resistance (ϕ ) values.

2. It is observed that the soil plus cement showed on average improvement of 24.7% in shear strength after 28 days curing.

3. It is observed that the soil plus lime showed on average improvement of 20.8% in shear strength after 28 days curing.

4. It is observed that the soil plus combination of cement & lime showed on average improvement of 18.06% in shear strength after 28 days curing.

5. The higher % improvement is in soil plus cement.

REFERENCES


