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Stabilization of Black Cotton Soil Using Lime

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ABSTRACT

Black Cotton Soils display high expanding and contracting when presented to changes in dampness content and consequently have been observed to be generally irksome from designing contemplations. Adjustment happens when lime is added to dark cotton soil and a pozzolanic response happens. The hydrated lime responds with the dirt particles and forever changes them into a solid cementitious network. Dark cotton soil showing low to medium expanding potential from Bhubaneswar, Odisha was utilized for deciding the fundamental properties of the dirt. Changes in different soil properties, for example, Liquid breaking point, Plastic Limit, Maximum Dry Density, Optimum Moisture Content, Differential Free Swell, Swelling Pressure and California Bearing Ratio were examined.

1. INTRODUCTION

Black soils have wide development in Bombay, western part of Madhya Pradesh, part of Gujarat, and in some parts of Madras. In Bombay, large area is occupied by soils derived from the Deccan trap. Black Cotton soils absorb water heavily, swell, become soft and lose strength. These soils are easily compressible when wet and possesses a tendency to heave during wet condition. Black Cotton soils shrink in volume and develop cracks during summer. They are characterized by extreme hardness and cracks when dry. These properties make them poor foundation soils and earth construction material. The stability and performance of the pavements are greatly influenced by the sub grade and embankment as they serve as foundations for pavements. For developing a good and durable road network in black cotton soil areas, the nature of soils shall be properly understood. On such soils suitable construction practices and sophisticated methods of design need to be adopted.

Characteristics of Black Cotton Soil

Black Cotton soils are inorganic clays of medium to high compressibility and form a major soil group in India. Black Cotton soil has a high percentage of clay, which is predominantly montmorillonite in structure and black or blackish grey in color. Because of its high swelling and shrinkage characteristics, the Black Cotton soil has been a challenge to geotechnical and highway engineers. The soil is very hard when dry, but loses its strength completely when in wet condition (Balasubramaniam, et. al, 1989). The wetting and drying process causes vertical movement in the soil mass which leads to failure of a pavement, in the form of settlement, heavy depression, cracking and unevenness. It also forms clods which cannot be easily pulverized as treatment for its use in road construction (Holtz & Gibbs, 1956). This poses serious problems as regards to subsequent performance of the road. Moreover, the softened sub grade has a tendency to heave into the upper layers of the pavement, especially when the sub-base consists of stone soling with lot of voids. Gradual intrusion of wet Black Cotton soil invariably leads to failure of the road. However, since this soil is available easily at low cost, it is frequently used for construction purposes (Bell, 1988).

Some of the factors which influence the behavior of these expansive soils are initial moisture content, initial dry density, amount and type of clay, Atterberg limits of the soil, and swell potential.

Lime Stabilization

Soil stabilization is a collective term for any physical, chemical, or biological method, or any combination of such methods that may be used to improve certain properties of a natural soil to make it serve adequately an intended engineering purpose. It is the process of blending and mixing materials with a soil to improve certain properties of the soil. The process may include the blending of soils to achieve a desired gradation or the mixing of commercially available additives that may alter the gradation, texture or plasticity, or act as a binder for cementation of the soil.

The main benefits of using lime to stabilize clays are improved workability, increased strength, and volume stability. Workability is improved because flocculation makes the clay more friable; this assists combination for effective mixing and compaction. Lime increases the optimum water content for compaction, which is an advantage when dealing with wet soil. The compaction curve for lime-treated clay is generally flatter, which makes moisture control less critical and reduces the variability of the density produced. In first few hours after mixing, lime additives cause a steady increase in strength, but at a slower rate than cement. The need for compaction immediately after mixing is therefore less critical for lime than cement. Lime increases the strength of clayey soil. Related to strength is improved durability under traffic or resistance to the action of water, wind, and freeze-thaw cycles. The shrinkage and swell characteristics of soil are reduced markedly. The lime stabilized layer forms a water-resistant barrier by impeding penetration of gravity water from above and capillary moisture from below.

Lime stabilization of clay soils is achieved in the field by shallow/surface stabilization or deep stabilization methods. Shallow stabilization using lime is achieved by mechanical mixing of lime and black cotton soil, spreading the mix and then compacting it. Deep stabilization involves the use of lime columns, lime piles or lime injection methods (Okumara, & Terashi, 1975). Mixing-spreading-compacting has the advantage over the lime pile technique that it ensures efficient contact between lime and clay mineral particles of the soil. A detailed study of the exact effects of lime addition to the properties of black cotton soil is needed so that it can be used as a reference in future construction works in such soils. Black soil specimens from the Latur district of Maharashtra were taken to study the effects of addition of lime on the properties of the soil.

2. TESTING PROGRAM OF BLACK COTTON SOIL

Black cotton soil from Latur was used for the determining the basic properties of the soil such as wet and dry sieve analysis, Atterberg Limits, Standard Proctor Test, Differential Free Swell Test, Swelling Pressure Test and California Bearing Ratio Test. The tests were performed on samples with lime content varying from 2.5% to 7.5% and then compared to the results obtained from soil without lime.

Sieve Analysis

Dry and Wet Sieve Analysis of the soil was performed in accordance with IS 2720 (Part 4)-1985 and were classified in accordance with IS 1498-1970.

Atterberg Limits

The Atterberg Limits of the soil were determined in accordance with IS 2720 (Part 5)-1985. The Atterberg Limits gave the Liquid Limit and Plastic Limit of the soil, from which the Plasticity Index was determined.

Standard Proctor Test

To assess the amount of compaction and the water content required in the field, compaction test (Standard Proctor test) was done on the soil in accordance with IS 2720 (Part VII) - 1980. The water content at which the maximum dry density is attained is obtained from the relationships provided by the test.

Differential Free Swell Test

Differential free swell test was carried out to determine free swelling index of soil (in accordance with IS 2720 (Part XL)-1977) from which the degree of expansiveness of soil was determined as per IS 2911 (Part 3)-1980.

Swelling Pressure

Swelling pressure is defined as the pressure which the expansive soil exerts, if the soil is not allowed to swell or the volume change of the soil is arrested. This test was carried out in accordance with IS 2720 (Part XLI)-1977.

California Bearing Ratio (CBR)

The CBR value of a soil is an index which is related to the strength of the soil. The test was conducted in accordance with IS 2720 (Part 16)-1987.

3. TESTINGRESULTS OFBLACK COTTON SOIL

Atterberg Limits

The Liquid Limit (LL) of the samples were determined and plotted against the lime content. (See Fig. 1). The liquid limit of untreated soil was determined as 59.8% whereas it varied between 53.2% to 59.5% after lime was added. The liquid limit of the soil decreases with increase in lime content up to 4.5% after that it goes on increasing with increase in lime content. Thus the optimum lime content is between 4-4.5% for maximum effect on liquid limit.

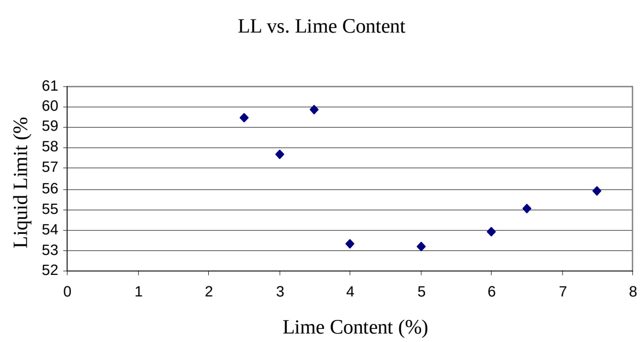

Fig. 1: Variations in Liquid Limit with Lime Content

Although the plastic limit did not change distinctly (range between 32% and 40%) with increase in lime content, the lowest value was reached at a lime content of about 4% as seen in Fig. 2. The plastic limit of untreated soil was determined to be 33%.

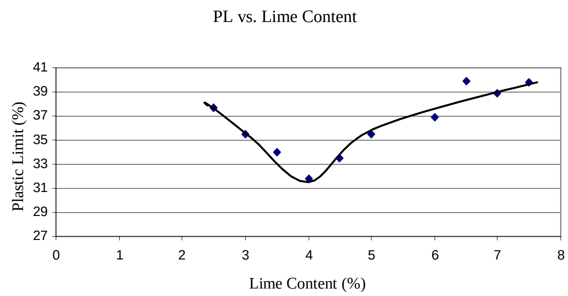

Fig. 2: Variations in Plastic Limit with Lime Content

The plasticity index decreased gradually with increase in lime content, see Fig. 3. The plasticity index varies from 25.9% to about15.1%. This shows that the plastic nature of the soil decreases and the stiffness of the soil increases as the lime content increases. Based on the sieve analysis and Atterberg Limit test results, the soil under consideration is classified as MH.

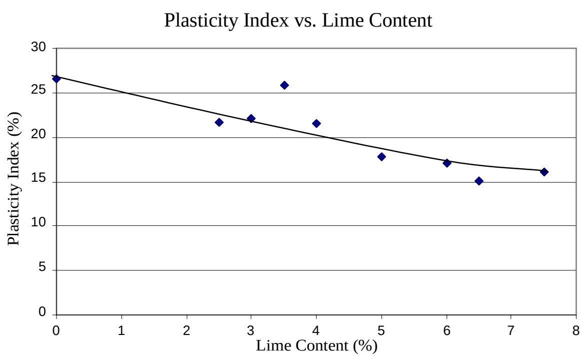

Fig. 3: Variations in Plasticity Index with Lime Content

Standard Proctor Test

The Standard Proctor Test results show that the maximum dry density remains constant with variation in lime content (Fig. 4) whereas the optimum moisture content (OMC) lies

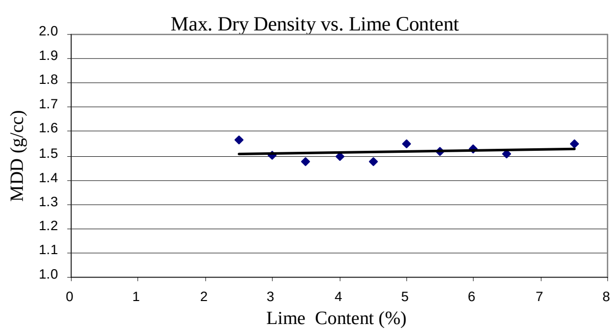

Fig. 4: Variations in Max. Dry Density with Lime Content

between 23-30% with a decreasing tendency as lime content increases (Fig. 5). So addition of lime did not improve the compaction characteristics of the soil under investigation (Prakesh, et. Al., 1989).

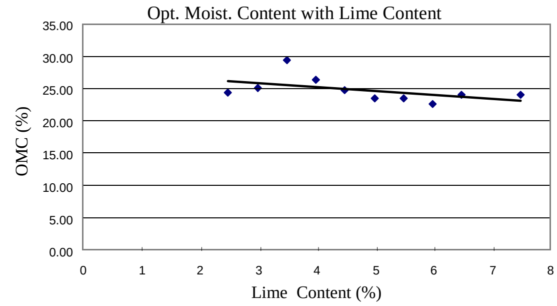

Fig. 5: Variations in OMC with Lime Content

Differential Free Swell Test

The differential free swell decreases gradually with increase in lime content as seen in Fig. 6. The variation in differential free swell was observed between 34.6% and 27.6% whereas the differential free swell for virgin soil was calculated as 39%

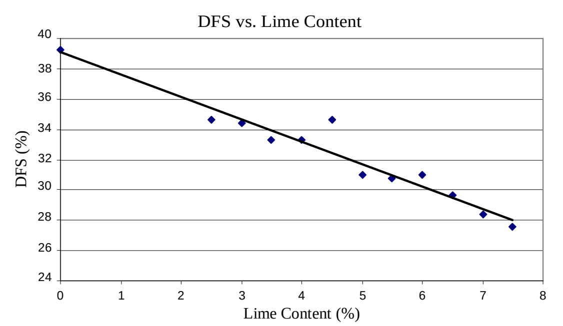

Fig. 6: Variations in DFS with Lime Content

Swelling Pressure

The swelling pressure of the untreated soil was calculated as 1.06 kg/cm^2. With the addition of a very small amount of lime (2%), the swelling pressure dropped to 0.42kg/cm^2. The swelling pressure decreases with increase in lime content up to 3.5% after which it goes on increasing. The optimum lime content is observed at about 3.5% where the swelling pressure was calculated as 0.22kg/cm^2. (Fig. 7)

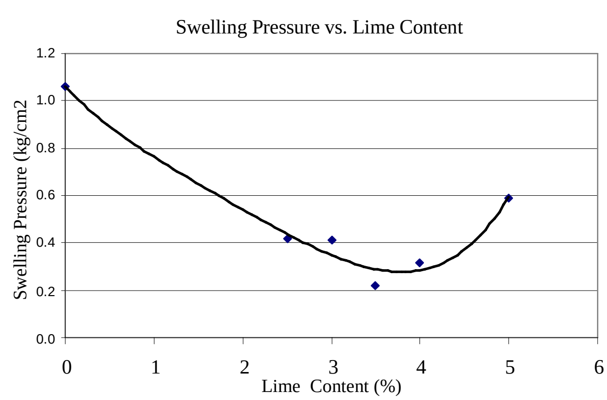

Fig. 7: Variations in Swelling Pressure with Lime Content

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California Bearing Ratio Test

The CBR value of the soil decreases with increase in lime content up to 3.5% after which it goes on increasing. The optimum lime content is observed at about 3.5%. (Fig. 8)

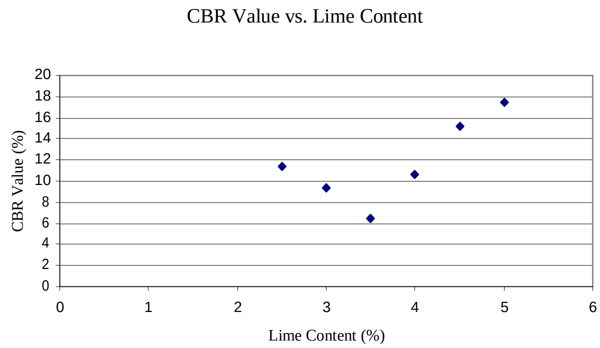

Fig. 8: Variations in CBR Value with Lime Content

4. DISCUSSIONAND CONCLUSIONS

An immediate benefit obtained by the addition of lime to swelling soils is to reduce the potential for swelling upon contact with water. The plastic nature of the soil decreases and the stiffness of the soil increases as the lime content increases. For improving the properties described in this paper, the optimum lime content was found to be within the range of 3.5% to 4.5% These values are found to be in general agreement with work carried out by other researchers (Ranganatham, 1961, Subba Rao, et. al., 1983).

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