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GEO ENGINEERING PROPERTIES OF LIME TREATED PLASTIC SOILS

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Abstract: For a long time, we are facing problems like failures of small and big structures. The biggest problem behind this is swelling soils. This is very unstable soil. Its property varies from hard to soft and dry to wet. It exhibits swelling and shrinkage with different water content. As a result, many structures usually face excessive settlement and differential movements, which causes damage to foundation systems and other structural elements. We are aware about this situation for a long time, but unable to make improvements due to absence of technologies till now. Expansive soils are found in many parts of the world like Burma, South Africa, Western USA, Cuba, Spain, Russia and Indonesia, etc. In India it is found in Rajasthan, Tamilnadu, Madhya Pradesh, Maharashtra, Gujarat and Orissa. Plastic soils undergo swelling and shrinkage causes severe distress and damage to the structure overlaying. Lime has been used as a soil stabilizer from Roman times. Through physico-chemical modifications, lime can control the plasticity, swelling and shrinkage of soil effectively. Also, lime can stabilize soil through cementation which increases strength and stiffness remarkably. This soil modification using lime depends on the type of soil and its mineralogy, lime content and compaction condition with curing period. The stabilizing effect of lime has been studied by a number of researchers. The minerals present in the soil has found to affect the engineering properties of stabilized material and the optimum lime content.

I. INTRODUCTION

Except some, which are founded on solid rock, rest ultimately on soil. Geotechnical engineers all over the world face huge issues, when structures founded on the soil which is expansive in nature. This expansiveness is imparted to such Soil is one of the most commonly encountered materials in civil engineering. All the structures soils when they contain clay minerals like montmorillonite, illite, kaolinite etc. in considerable amount. Due to the clay minerals, the swelling soils expand on wetting and subjected to shrinkage on drying. These soils are commonly unsaturated. The problem of instability of structures made on such soil is mainly due to lifting up of the structures on heaving of soil mass under the foundation on saturation during rainy season and settlement as a result of shrinkage during summer season. Due to this cavity formed, leading to loss of contact between the soil and structures at some points. This successively results in splitting of structure and failure due to loss of shear strength or unequal settlement.

II. LITERATURE SURVEY

The term expansive soil indicates to soils, which has the tendency to swell when their moisture content is allowed to increase. The water may come from rain, flooding, leakage of water from sewer lines or from a reduction in surface evapotranspiration when an area is covered by a building or pavement. The term cracking soil is also used for these soils as they have the tendency to shrink and crack when the moisture is allowed to decrease. Soils containing the clay mineral montmorillonite generally show these properties (Komine and Ogata, 1996; Rao and Triphaty, 2003).

III. EXPANSIVE SOIL

Expansive soils are mostly found in arid and semi-arid regions of the world. The presence of montmorillonite clay in these soils imparts them swell-shrink potentials (Chen, 1988).

Expansive soils cover nearly 20% of the landmass in India and include almost the entire Deccan plateau, Western Madhya Pradesh, parts of Gujarat, Andhra Pradesh, Uttar Pradesh, Karnataka, and Maharashtra (Gopal Ranjan and Rao, 1991)

In general, expansive soils have high plasticity, and are relatively stiff or dense. The expansive nature of the soil is most obvious near the ground surface where the profile is subjected to seasonal and environmental changes. The pore water pressure is negative initially and the deposit is generally unsaturated. These soils contain some montmorillonite clay mineral. The expansive soil problem is dependent on the amount of monovalent cations absorbed to the clay mineral like sodium (Fredlund and Rahardjo, 1993).

The particles of clay have high negatively charged surfaces that attract free positively charged cations and water dipoles. Thus, a diffused water layer is formed around the clay particles and separates the clay particles which make the clay weak and unstable. This phenomenon depends upon the amount of water present, morphology and mineralogy of the clay. (Little, 1987).

Problems associated with expansive soil

Expansive soils have been called the hidden disaster as the damage cost is more than the combined damage from natural disaster such as earthquakes, and floods (Jones and Holtz, 1973).

Expansive soils are a worldwide issue that poses many challenges for civil engineers. These are considered a potential natural hazard, which may cause extensive damage to the structures if not properly treated. Such soils swell when giving an access to water and shrink after they dry out (Al-Rawas et al., 2002).

The issues with foundations on expansive soils have included heaving, cracking and break-up of pavements, roadways, building foundation, slab-on-grade members, channel and reservoir linings, irrigation systems, water lines, and sewer lines (Cokca, 2001).

It is reported that damage to the structures due to expansive soils has been the most costly natural hazard in some countries (in United States more than the cost of damage from flooding, hurricanes, tornados and earthquakes on an average annual basis) for years (Kehew, 1995; Shuai and Fredlund, 199

IV. MATERIALS AND METHODS

I Expansive soils creates greatest hazard in arid regions. Expansive soils contain clays and fine silts swells and shrinks as their moisture content changes. These expansive soils created problems for the structures, mainly lightweight structures and the structures most commonly damaged are small buildings, roadways, pipelines and irrigation canals.

The moisture in the soils shows variations due to climatic changes, change in water table, watering of gardens and lawn, presence of trees and shrubs and leakage from water and drainage pipes.

Origin and occurrence of expansive soils

Clay mineral is that the key component that passes on swelling characteristics to any standard non-swelling soils. Montmorillonite has the utmost swelling potential among many varieties of clay minerals. The origin of such soil is sub aqueous decomposition of blast rocks, or weathering in situ formation of vital clay mineral takes place under alkaline environments. If there is an adequate supply of magnesium of ferric or ferrous oxides and alkaline environments along with adequate silica and aluminum attributable to weathering condition, it will favor the formation of Montmorillonite. The depth is not deeper at the place of formation for clay with the parent rock beneath. The alluvium deposits may be much deeper in low lying areas, where these soils are transported and deposited.

Problems associated with expansive clay

For all types of engineering constructions over expansive soils are not appropriate since they create issues. However, owing to persistence of those kinds of soils in several parts of India, different irrigation projects are required to be developed on these deposits. Furthermore, examples of similar issues have also been recognized in many other parts of the globe. Structures found in these soils are subjected to differential deflections that cause distress on swelling clays and produce dangerous damage to the buildings and superstructures. Reduction of water content causes shrinkage by the evaporation of vegetation, whereas a continuous increase in moisture content causes heave in expansive soil like bentonite. The rise of the water table has got a notable impaction the movement of foundation on expansive soils

Clay mineralogy

Clay minerals, an important group of sheet silicate family of minerals, which are distinguished by layered structures composed of polymeric sheets of SiO_4tetrahedra linked to sheets of (Al, Mg, Fe)$(O,OH)_6$octahedra. The geotechnical importance of clay minerals stains from their ubiquity in soils and sediments, high specific surface area, and ion exchange capacities. Clay minerals tend to dominate the surface chemistry of soils and sediments. The clay minerals form a difficult group of minerals to study due to their small size, variable structural composition, and relative slow kinetics of formation and alteration.

Structure of clay minerals

Clay minerals are primarily the end product produced by chemical weathering of feldspathic rock. Chemically, these minerals are basically hydrous aluminum silicates, although often the aluminum atoms are replaced with atoms of 5other elements, such as magnesium, iron, potassium, or sodium (Duncan, 1992). The atomic structure of a clay mineral is very complex, and consists of a variety of combinations and arrangements of two basic building blocks called the silica tetrahedron and the alumina octahedron as shown in Figure 1.1.

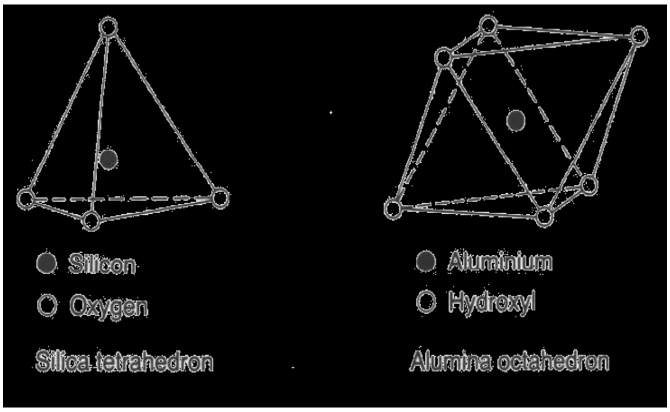


Figure 1.1 Basic units of clay minerals (Craig, 1993)

The various building blocks those make a clay mineral are arranged in orderly sheets are shown in Figure 1.2 (a) and Figure 2 (b). The particular arrangement and chemical compositions of these building blocks determines the type of clay mineral and its general characteristics.

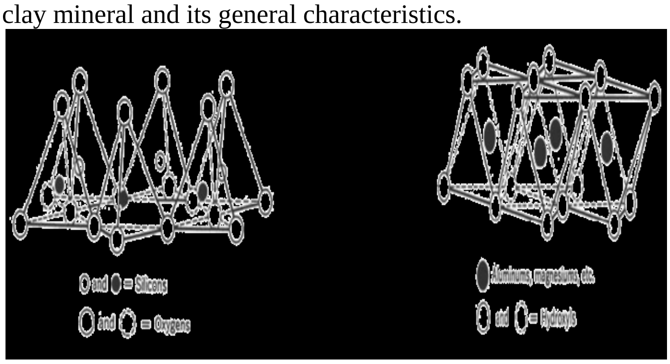


Figure 1.2 (a) Silica sheet and (b) Octahedral sheet (Mitchell, 1993)

Major clay groups

Clay minerals are grouped according to chemistry, and its interaction with water. The three main groups of clay are
a) kaolinite, b) illite, and c) montmorillonite

MATERIAL USED

An experimental program has been done taking highly expansive montmorillonite soil and a residual silty soil. Four types of plastic soils have been prepared from the raw soils. These artificial soils are added with different proportions of lime and a series of tests were conducted.

Primarily, an expansive soil and a residual soil, which represent the extreme soil type, are used in this study. The expansive soil is a commercially available bentonite. Its liquid limit and plastic limit are found to be 340% and 68%. The liquid limit and plastic limit of the residual soil are found to be 34% and 18% respectively. As per Indian standard soil classification system for fine grained soil as shown in Figure 3.1, the expansive soil is classified as clay with high plasticity and the used residual soil is classified as clay with low compressibility following Table 3.1. **Lime**

A laboratory hydrated lime [Ca (OH)2] was used as the stabilizing agent. The specific gravity of the lime used is found to be 2.4.

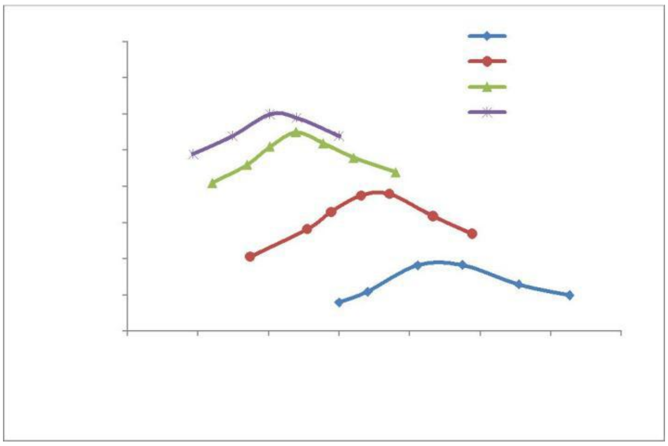
SAMPLE PREPARATION AND EXPERIMENTAL PROGRAM

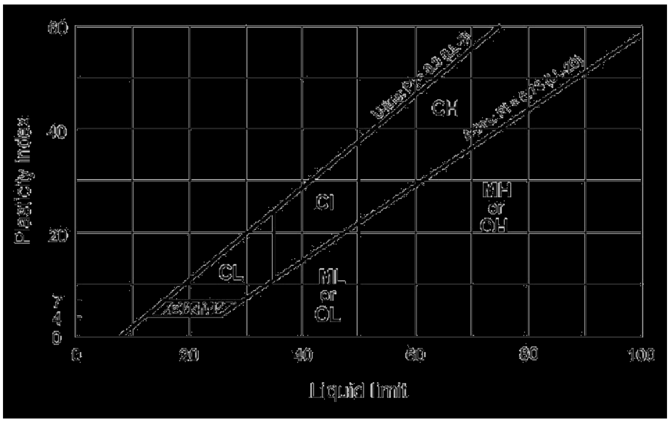
To cover a wide range of plasticity, four different soil samples were constituted by mixing the expansive soil and residual soil in different proportions (i.e. 100% expansive soil, 50% expansive soil with 50% residual soil, 10% expansive soil with 90% residual soil, 100% residual soil). All of these soils amended with different percentage of lime (i.e. 0, 2, 5, 9, 13 percentage by weight of dry soil) and various engineering properties were studied by conducting the experiments. Liquid limit tests are done using a mechanical liquid limit device, whereas the plastic limit is obtained by the thread rolling method as per IS : 2720 (Part 5)-1985. The free swell index is determined as per IS: 2720(part XL) -1977. The linear shrinkage has been determined as per IS: 2720 (Part 20) - 1992. The Optimum moisture content and dry density of soils were determined by performing the “standard proctor test” as per IS: 2720 (part VII) - 1965. The strength improvement of soils will be evaluated using the “unconfined compressive strength (UCS) tests”

V. METHODOLOGY

Lime stabilization of plastic soils reduces the problems associated with constructions faced by the expansiveness of these soils, mostly because of its swell and shrinkage property. So assessment of the behavior of plastic soil at different condition is required before commencing the construction activity. Even through adequate substitute for full scale field tests are not available, tests at laboratory scale provide a measure to control many of the variable encountered in practice. The trends and behavior pattern observed in the laboratory tests can be used in understanding the performance of the structures in the field and may be used in formulating mathematical relationship to predict the behavior of field structures. Details of material used, sample preparation and testing procedure adopted have been outlined in this chapter.

GRAPHS





VI. CONCLUSIONS

Many of the important engineering properties of soils can be enhanced by the addition of lime. The properties of such soil-lime mixtures vary and depend upon the type of soil. To develop an understanding of the possible mechanisms involved, a series of experiments through variation of parameters were carried out, based on which the following conclusions are drawn:

The liquid limit of soil decreases with an increase in lime content. This result is obtained due to reduction in thickness of double layer as the electrolyte concentration increases in the pore fluid.

1. The plastic limit of soil increases with lime contents as the charge concentration of pore water increases, the viscosity increases and offers high resistance against interparticle movement.
2. The plasticity of soil reduces with increased lime content.
3. There is a significant reduction in free swell index of high plastic clay at low lime content in comparison to other low and medium plastic clays.

4. The amount of shrinkage arrest caused by addition of lime correlated with raw soils specific surface area. More shrinkage occurred for high plastic clays.
5. The compaction characteristics of soils vary significantly at low lime content. The optimum moisture content increases and maximum dry density decreases with increased lime content.
6. The strength of lime treated soil depended on type of soil,

lime content, curing period and moisture content. For high plastic clays maximum strength was achieved at 60 days cured sample with 9% lime content whereas, for low plastic clay occurred with 5% lime.

7. More strength is achieved at dry side of optimum than wet side of optimum moisture content for virgin soils. When the soils are cured for 28 days with varying moisture content, there is a significant increase in strength for high plastic clays when treated with high lime content with high moisture content, and for low and intermediate plastic clay, at comparatively low lime content.

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