International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Special Issue – NCITTATME'21

STABILIZATION OF BLACK COTTON SOIL USING CALCIUM CARBIDE RESIDUE

Aditi. R. Badhe, Student, MIT-COM, Pune, India, baditi97.ab@gmail.com
Saurabh. V. Samel, Student, MIT-COM, Pune, India, saurabhsamel90@gmail.com
Prof. Shankar Banerjee, Guide, Asst. Prof.-MITCOM-PCM Dept., MIT-ADT University, Pune, shanker.banerjee@mituniversity.edu.in

Abstract: Calcium carbide residue (CCR) which has chemical formula [$Ca(OH)_2$] is a waste product from acetylene gas factories. Stockpiles of CCR continue to accumulate worldwide, in both developed and developing countries. Sustainable reuse options for CCR in civil infrastructures, such as road embankments, have been recently evaluated in the laboratory. However, to date there are limited studies on the actual field performance of CCR in stabilizing clayey soils in highway subgrades. CCR is rich in calcium hydroxide and clayey soils contain high amount of natural pozzolanic materials (silica and alumina). This project is aimed at using CCR for improving the chemical properties of Black Cotton Soil.

Keywords —Alkalinity, Black cotton soil, CBR value, Calcium carbide residue, Direct Shear Strength, economical. , environment,

I. INTRODUCTION

1.1 Background

The existence of expansive soil on construction sites may cause partial or full damage to the structures built on it. The problems with foundations on expansive soils include heaving, cracking and breaking of pavements.

1.1.1 Black Cotton Soil

The black soils are also called regur (from the Telugu word Reguda) and black cotton soils because cotton is the most important crop grown on these soils. Several theories have been put forward regarding the origin of this group of soils but most penologists believe that these soils have been formed due to the solidification of lava spread over large areas during volcanic activity in the Deccan Plateau, thousands of years ago. Black Cotton Soil is known to be one of the problematic soils. This is due to the large change in its volume when subjected to wetting and/or drying. Under saturation conditions, expansive clays tend to swell and lose shear strength. If swelling is prevented, they develop swelling pressure. Moreover, under dry conditions, they shrink and exhibit cracks due to localized volume changes. Expansion or swelling problems are more predominant than shrinkage. Thus black cotton soil should be technically treated to prevent such damage.

1.1.2 Calcium Carbide Residue

Calcium carbide residue (CCR) is a by-product of acetylene gas production. Stockpiles of CCR continue to accumulate worldwide, in both developed and developing countries. Sustainable reuse options for CCR in civil infrastructures, such as road embankments, have been recently evaluated in the laboratory. In most case CCR is not treated properly and is dumped outside acetylene gas factories. This is harmful for the environment as well as for people living in the vicinity.

1.2 Relevance

Structures constructed on black cotton soil induce heaving due to a variety of reasons. Shrinkage from the reduction of moisture content caused by evaporation or the transpiration by vegetation, and the subsequent increase in soil moisture content cause heaving in expansive soils. The environmental conditions of a particular area in which expansive soils are located play an important role in the behavior of such soils. The frequency and total amount of rainfall, ate of evaporation, depth of expansive soils and the activity of the soil are the parameters influencing the eventual heaving of expansive soils. The expansive nature of soil is generally attributed to the presence of the specific clay mineral montmorillonite. Montmorillonite has an expanding lattice structure. Water can easily be absorbed into the lattice, causing expansion.

1.3 Literature Survey

Several methods have been used to reduce the detrimental effects of expansive soils. There are numerous methods by which soils can be stabilized; however, all stabilization methods fall into two broad categories. They are mechanical stabilization and chemical stabilization. Mechanical soil stabilization relies on physical processes to stabilize the

 DOI : 10.35291/2454-9150.2021.0479

soil, either altering physical composition of the soil by mixing with another soil and mixer (soil blending) or placing a barrier in or on the soil. Mechanical stabilization involves compaction and interlocking of soil particles. The grading of the soil–aggregate mixture must be such that a dense mass is produced when it is compacted. Mechanical stabilization through soil blending is the most economical and expedient method of altering the existing material.
Chemical stabilization relies on the use of an admixture to alter the chemical properties of the clayey soils in order to achieve the desired effect. The competitiveness of lime treatment has increased due to the rarefaction of granular materials and the low cost of the lime. In practice, lime is used as an effective additive to improve various engineering properties of cohesive soils. Generally, lime treatment in clay soils causes a decrease in plasticity, volume change and an increase in permeability. Such changes in properties can be explained by two types of chemical reactions that occur when lime is added to wet soil. There is a short-term reaction, which is soil improvement or modification, consisting of cation exchange and flocculation, and a long term reaction which is stabilization/solidification by the pozzolanic activity. The immediate reactions due to soil–lime treatment starts with the cation exchange between the ions associated with the surfaces of the clay particles and the calcium ions of the lime. The clay particles are surrounded by a diffuse double layer modified with calcium ion exchange. This reaction alters the density of the electrical charge around the clay particles and so the particles are attracted closer to each other to form flocks. During the first stage, improvements occur immediately with respect to soil plasticity, workability, swell and shrinkage properties, and permeability. In addition to cation exchange, a reaction occurs between the silica and some alumina of the lattices of the clay minerals, especially at the edges of the clay particles. During this process, the highly alkaline environment produced by the addition of lime causes silica and alumina to be dissolved out of the structure of the clay minerals. Additionally, they combine with the calcium to produce new cementitious compounds: calcium silicate hydrates, calcium aluminate hydrates (CAH) and calcium alumino-silicate hydrates (CASH).For maximum reactivity between lime and clay, the pH value of the pore fluids should remain at around 12. In the present research, highly expansive clay is mixed with calcium hydroxide for chemical stabilization.

1.4 Motivation

Black cotton soil is found in most parts of Maharashtra, Gujarat, Madhya Pradesh and Karnataka. Construction on this soil come with many technical problems, and even after construction the structures can be severely damaged due to the excessive swelling of soil. For construction on this soil the soil is either replaced or is stabilized using expensive techniques. Economical construction on black cotton soil in rural areas is the main motivation behind this project.

1.5 Problem Definition

The aim of this project is to tackle the problem of construction on black cotton soil due to the excessive swelling property of the soil. Other implementation problems of stabilizing the soil with CCR are also to be tackled in this project.

1.6 Scope and Objective

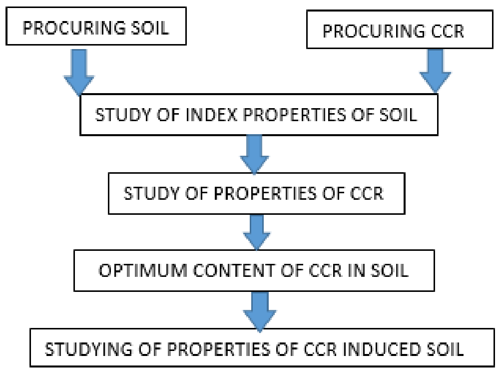
There is abundance of black cotton soil in central region of India which makes construction in these regions uneconomical. A solution to this problem can help in making many projects economical. The objective of this project is to implement this stabilization process on site.

1.7 Technical Approach

All the index and engineering properties of soil and computed and the same properties are calculated again after the addition of CCR. This give a clear difference between the behavior of soil with and without CCR.

II. METHODOLOGY

The methodology of this project is designed after a thorough study of properties of soil and CCR and referring various other research papers related to this topic. This methodology gives a clear comparison between the properties of black cotton soil with and without CCR.



EFFECT OF CCR ON SOIL

The hydration and pozzolonic reaction process in cement stabilized clay can be explained as follows: when water comes in contact with cement, cement hydration occurs rapidly. The major hydration products are hydrated calcium silicates (CSH), hydrated calcium aluminates (CAH), hydrated calcium aluminum silicates (CASH), and hydrated lime [$Ca(OH)_2$]. This hydration leads to a rise in the pH value of the pore water that is caused by the dissociation of [$Ca(OH)_2$]. The strong bases dissolve the silica and alumina from the soil in a manner similar to the reaction between a

 DOI : 10.35291/2454-9150.2021.0479

ISSN : 2454-9150 Special Issue – NCITTATME'21

weak acid and a strong base. The hydrous silica and alumina will then gradually react with calcium ions liberated from the hydrolysis of cement from insoluble compounds (secondary cementitious products), and harden with time. Consequently, from an economic and environmental viewpoint, some waste [$Ca(OH)_2$]rich materials can be used together with pozzolanic materials, such as fly ash, biomass ash, and rich hush ash, to develop a cementitious material. Calcium carbide residue (CCR) is a byproduct of the acetylene production process, that mainly contains calcium hydroxide, [$Ca(OH)_2$], hence it can be used instead of using cement.

III. TESTS CONDUCTED

Following are various test results performed on Black Cotton Soil and CCR.

1. Water content in Soil and CCR
2. Free swell index of soil
3. Specific gravity of Soil and CCR
4. Alkalinity of soil and CCR
5. Atterberg's consistency limits of soil
6. Particle size distribution of soil using hydrometer analysis.
7. Direct shear test
8. CBR test

HYDROMETER ANALYSIS

- The swelling property of the soil is governed by the percentage of clay particles present in the soil. Particle of size less the 2 microns are categorized as clay particles. We have performed wet sieve analysis to find particle size distribution. It was found that 94% particles of the sample are clay particles as they passed through 2 micron sieve.
- As 94% particles are passing through 2 micron sieve, it is important to perform particle size distribution of particles passing through 2 micron sieve. We have use hydrometer test to obtain particle size distribution of particle passing through 2 micron sieve.
- As clay particles govern the swelling of soil it is important to focus on the percentage of clay particles

IV. TEST RESULTS

1. Water content of soil and CCR

SR. NO	*Description of item*	*Water Content*
1	Soil	18.1%
2	CCR	86%

2. Free swell index of soil

The free swell index of the soil is found out to be 86% which shows that the soil is of high swelling potential. High free swell index also indicated that the soil has an higher amount of montmorillonite.

3. Specific gravity of soil and CCR

SR. NO	*Description of item*	*Specific gravity*
1	Soil	2.58
2	CCR	2.16

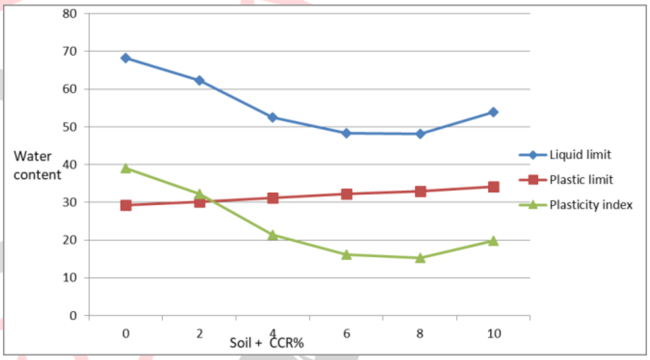
4. Alkalinity of soil and CCR

SR. NO	*Description of item*	*pH*
1	Soil	7.74
2	CCR	12
3	Soil + 2% CCR	8.6
4	Soil + 4% CCR	9.5
5	Soil + 6% CCR	11.10
6	Soil + 8% CCR	11.44
7	Soil + 10% CCR	11.80

For maximum amount of CSH gel to be formed by reaction between calcium present in CCR and silica present in soil it necessary that alkaline conditions are present in the soil and the pH of soil is more than 11.

In the above results in can be observed that the pH of soil goes on increasing with increase in the amount of CCR. At 8% CCR the pH of soil is 11.44 which shows that the soil has favorable condition for the formation of CSH gel.

5. Atterberg's consistency limits of soil

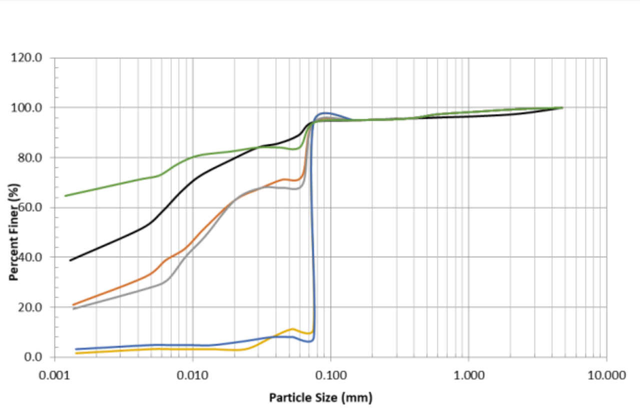


According to past research papers published, the optimum percentage of CCR to be added is 6% to 8%. To obtain the optimum percentage of CCR to be added a graph of percentage of CCR vs. plasticity index is drawn. From the graph the optimum amount of CCR to be added is 7%.

6. Particle size distribution

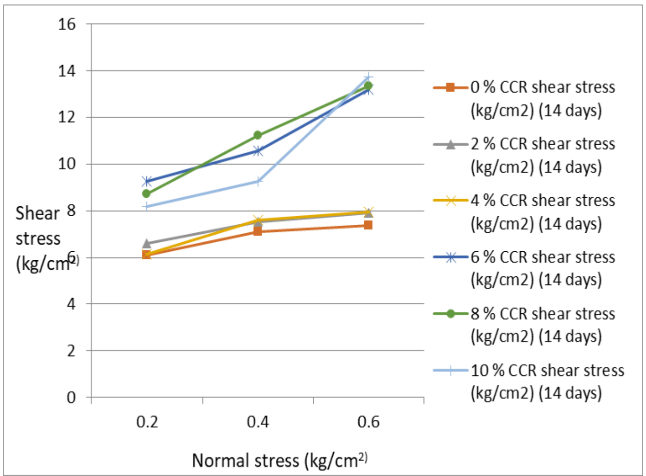
Wet sieve analysis was conducted on 1000 grams of oven dried soil.

DOI : 10.35291/2454-9150.2021.0479



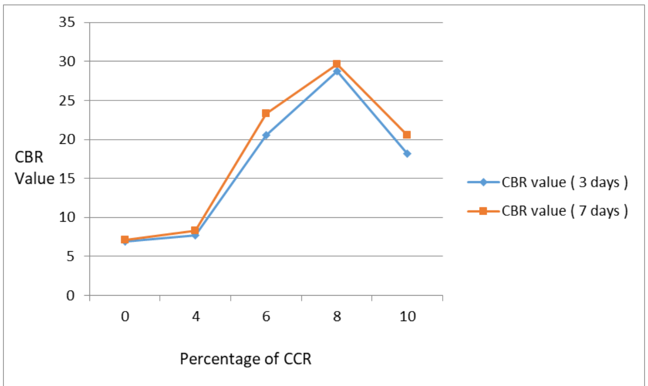
After plotting the graphs of hydrometer analysis with varying percentages of CCR it can be observed that, when the percentage of CCR is more than 6 there is a considerable increase in the particle size of the soil. This indicates that due to the adding of CCR and formation of CSH gel agglomeration of clay particles has taken place and the effective size of particles in the soil has increased. The increase in the particle size also contributes in increasing the coefficient of friction which increases the shear resistance of soil and reduces its sensitivity towards water.

7. Direct shear test



It can be clearly observed that with increase in percentage of CCR added to soil there is considerable increase in the shear strength of soil, with 10% CCR giving maximum shear strength of 11.2 kg/sq.cm.

8. CBR test



It can be clearly observed that with increase in percentage of CCR added and increase in the curing period of soil, the CBR value of soil has increased significantly. CBR value of soil with CCR is 2-3 times more than the CBR value of soil without CCR.

V. CONCLUSION

After reading various research papers and studying the properties of CCR it was found that CCR when added in soil reacts with the silica and alumina present in the soil and forms CSH gels which has cementitious properties.

After performing various tests it was found that 7% CCR gives maximum reduction in the plasticity index of the soil, making the soil less sensitive to moisture content.

Using CCR as a stabilizing agent in black cotton soil the swelling property of the soil can be reduced economically as CCR being a waste material by product of industry is cheaper than use of lime. It also results in benefitting the environment as a waste material is successfully utilized.

Thus, it can be concluded that with large scale testing and experimentation, Calcium Carbide Residue can be effectively used to improve the properties of expansive sub-grade soils.

REFERENCE

[1] Soil Stabilization by Calcium Carbide Residue and Fly Ash (2012)- Suksun Horpibulsuk, Ph.D., Chayakrit Phetchuay and Avirut Chinkulkijniwat, Ph.D.

[2] Engineering Properties of Silty Clay Stabilized with Calcium Carbide Residue (2013) - Apichit Kampala and Suksun Horpibulsuk, Ph.D.

[3] Field evaluation of soft highway subgrade soil stabilized with calcium carbide residue (2016) - Yan-Jun Du, Ning-JunJiangb,, Song-YuLiu, SuksunHorpibulsuk, ArulArulrajah (published in The Japanese Geotechnical Society).

[4] Stabilization of highly swelling clay using lime-sand mixture(2017)-Tom Schanz, Mohamed B. D. Elsawy

[5] Manual of soil laboratory testing, volume 1-K.H. Head

[6] Soil mechanics- B.C.Punmia

[7] IS 2720- all parts

 DOI : 10.35291/2454-9150.2021.0479