Evaluation of Strength Characteristics of Clayey Soil Using Rice Husk Ash and Calcium Chloride

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Abstract - A number of researchers have recently been interested in Black Cotton (BC) soil stabilization. In the past, black cotton soils were stabilized using calcium chloride (CC) and rice husk ash (RHA). The authors used both of them simultaneously in an attempt to stabilize BC soils. The current study aimed to assess the soil stabilizing efficacy of different ratios of rice husk ash and copper slag. A number of researchers have recently been interested in Black Cotton (BC) soil stabilization. In the past, black cotton soils were stabilized using calcium chloride (CC) and rice husk ash (RHA). The authors used both of them simultaneously in an attempt to stabilize BC soils. The current study aimed to assess the soil stabilizing efficacy of different ratios of rice husk ash and copper slag. The mixed proportion of BC soils, calcium chloride, and rice husk ash were subjected to compaction tests, Atterberg's limits, and the California Bearing Ratio (CBR). There aren't many studies on the usage of calcium chloride and rice husk ash together for soil stabilization. There was just a slight change in the treated soil's maximum dry density. The combinations of stabilized soil have shown good strength characteristics and can be used for low-cost construction projects like building roads and houses.

***Key Words*:** Compaction test, CBR, UCS, Rice Husk Ash, Calcium Chloride

INTRODUCTION

We know that India is a developing country and the requirement for industrial and infrastructure projects has been increased significantly in last two decades. For any infrastructural project foundation is the most essential part. For a rigid foundation, it should be ensured that the soil mass beneath it is adequately strong to bear the load of substructure. However at certain sites this condition may not always be fulfilled due to poor shear strength of soil. Most of the part in India is covered with clayey soil which generally shows poor geotechnical properties like poor shear strength, poor drainage characteristics, high shrinkage etc. Strength parameters are the main factors of soil to maintain the stability of structure. Clayey soil comes under expansive soils and it contains minerals such as montmorillonite, smectite etc. which are highly capable of absorbing water. When they absorb water, there occurs increase in volume of soil. The more water they absorb, the more their volume increases. And when water content decreases, the soil starts to shrink. This alternate swelling and shrinkage causes huge amount of change in the volume of the soil and results in damaging the structure. This change in volume also cause differential settlement which is very dangerous to any type of structure built on it. Cracked foundation, floors and basement walls are typical types of damage done by swelling of soils.

2. Literature Review

Kumar et al. (2023)

This study aims to determine how the mixture of sawdust ash and rice husk ash affects the electrical properties of black cotton. For all mixed models, different concentrations of rice husk ash of 0, 3, 6, 9, 12 and 15% (based on the weight of black soil) were added to the soil compared to sawdust ash at 6% by weight of the soil. cotton soil. To evaluate the electrical properties of soils and their mixtures, tests such as Attenberg Limit, Specific Gravity, Particle Size Distribution, Standard Proctor Test, Unconstrained Compressive Strength (UCS) and California Bearing Ratio (CBR) are performed. The results showed that the addition of 9% wheat hull and 6% wood ash greatly improved the electrical properties of black cotton.

Vishal Kumar et al., (2022) In the field of civil engineering, stabilization of soil is a procedure to improve and enhance the engineering properties of soil in such a manner that it can withstand heavy loads without any failure. In current work, the behaviour of soil after adding the rice husk ash (fixed proportion 10%) and sisal fibre (varying proportion 0.5%, 0.75% and 1%; varying length 20 mm and 40mm) was studied at different proportions and then different soil properties like, OMC, MDD, CBR value and UCS values were determined.

Chandrakaran et al. (2021) The studies used soil that had only been treated with fly ash and nylon fiber. First, the methods used to determine the ideal fly ash that may be employed in untreated soil. In addition, different amounts of nylon fiber (0.25 and 0.5) were applied at different fly ash percentages (10, 20, 30 and 40), and the ideal was discovered.

To determine the optimal percentage, a supervised test was performed and strength was measured using a compressive strength test. The optimum nylon fiber and fly ash (from heavy soil) are 0.25 percent and 20 percent, respectively. The effect of positive percentage on the compressive strength and plastic properties of cultivated soil was tested at application periods of 1 day, 7 days and 28 days. This study shows that the strength of the soil stabilized with nylon fibers and fly ash increases, and the soil tillage strength also increases in the case of the combination of fly ash and nylon fibers.

Kumar Abhimanyu Bhardwaj et al. (2019) The engineering strength properties of expensive soils (clayey soil) such as compaction characteristics and bearing capacity can be improved by stabilization process of the soil. These properties can be improved by controlled compaction using the mechanical equipment's or by addition of suitable admixtures like cement, fly ash, lime, gypsum or by reinforcing the soil with shredded tyre, crumb rubber, plastic waste etc. But gypsum is used now a day to enhance the geotechnical properties. So, in this research paper gypsum and calcium chloride has been used to improve the various strength properties of natural soil. The objective of this research paper is to investigate the strength properties of natural clayey soil reinforced with different percentage of gypsum by the weight of soil and fixed percentage of calcium chloride as a binding material. A series of Standard Proctor test, Free swell Index and California Bearing Ratio (CBR) tests are conducted on both natural soil and reinforced soil with varying percentages of gypsum (2%, 4%, 6% and 8%) by weight and fixed percentage of calcium chloride (1%).

Jeetender Kumar et al. (2019) In this research, RHA and CaCl2 are combined with different proportions like, RHA as 7%, 14%, 17%, and 21% along with CaCl2 as 5% for improving the expansive nature of clayey soil. The results obtained shows that the increase in the

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percentage of CaCl2 and RHA decrease the liquid limit, plastic limit leading to significant reduction in plasticity index. This in turn, increased the maximum dry density and decreased the optimum moisture content which results in greater strength. The unconfined compressive strength of soil stabilized with **5% CaCl2 and 17%** RHA increased approx. by 64% and 3 to 4 times in CBR value as compared to virgin soil.

Karim et al. (2018)

The main purpose of this study is to stabilize clay sample s by mixing sawdust ash (SDA) at different concentration s (0%, 2%, 4%, 6%, 8% and 10% of dry soil weight). Stu dies have shown that the presence of clay causes the liqui d limit and plasticity index of the soil affecting the soil. T he addition of sawdust to fine clay improves the bulk and strength of the soil, as demonstrated by a decrease in spec ific and maximum dry density (MDD) as well as a decrea se in compressibility (Ccan and Cr) and an increase in SD A. contents. Both the observed moisture content (OMC) a nd the undrained shear strength (cu) increased with increa sing SDA concentration.

P. Bharath Goud et al. (2018) Present study was undertaken to evaluate the effectiveness of different percentages of rice husk ash and copper slag as soil stabilizers. The tests performed on the mixed proportion of BC soils, Copper Slag and Rice Husk Ash are Vane shear, California Bearing Ratio (CBR), Atterberg limits, free swell index (FSI), and compaction tests. Limited studies have been reported for the combination of copper slag and rice husk ash in soil stabilization. The optimum mix was found to be in the proportion of 64%BC+30%CS+6%RHA. FSI of soil treated with RHA+CS decreased steeply from 100% to 20.4%. There was a slight change in maximum dry density of the treated soil. The unsoaked CBR test shows that strength of optimum mix was 12.7%. The stabilized soil mixtures have shown satisfactory strength characteristics and can be used for low-cost constructions to build houses and road infrastructure Laboratory vane shear tests have been carried out under undrained conditions to study the shear strength parameters of the stabilized soil.

Srikanth et al. (2017) Soil stability is an important criteria in the field of construction. For soil which lacks sufficient stability, various stabilization techniques can be adopted. Stabilization can increase the shear strength of soil and control the shrink-swell properties of soil, thus improving the load bearing capacity of the sub-grade to support pavements and foundations. A vast diversity of stabilization techniques exist. The focus of this report is to study the feasibility of stabilizing soil by using rice husk ash and coir fiber, thus re-using waste materials and providing an economical and eco friendly method of soil stabilization.

P. Bharath Goud et al. (2016) Present study was undertaken to evaluate the effectiveness of different percentages of rice husk ash and copper slag as soil stabilizers. The tests performed on the mixed proportion of BC soils, Copper Slag and Rice Husk Ash are Vane shear, California Bearing Ratio (CBR), Atterberg limits, free swell index (FSI), and compaction tests. Limited studies have been reported for the combination of copper slag and rice husk ash in soil stabilization. The optimum mix was found to be in the proportion of 64%BC+30%CS+6%RHA. FSI of soil treated with RHA+CS decreased steeply from 100% to 20.4%. There was a slight change in maximum dry density of the treated soil.

Ch.Mahesh et al. (2016) In this investigation, an attempt has been made to study the possibility of utilizing rice husk, lime &fibers these are the hazardous industrial waste for stabilization of soil, since bulk utilization of rice husk, lime &fibers is feasible in the case of geotechnical applications like construction of embankments, earth dams, and highway and air field pavements. Soil stabilization is the process of improving the engineering properties of the soil and thus making it more stable. It is required when the soil available for construction is not suitable for the intended purpose. In its broadest senses, stabilization includes compaction, preconsolidation, drainage and much other such process. However, the term stabilization is generally restricted to the process which alters the soil material itself for improvement of its properties. A cementing material or a chemical is added to a natural soil for the purpose of stabilization.

Shon et al. (2016) reported that treatment of soil with calcium chloride increases the density and strength of the compacted soil. Further it increases the surface tension of the retained moisture within the soil matrix, thus increasing the suction pressure of the system. Thus in turn, increases the cohesive energy between the particles which result I greater strength.

Hilbrich and McDonald (2016) conducted unconfined compressive strength, triaxial compressive strength and suction tests using the calcium chloride and F class Fly ash. High strength was obtained by using the filter cake and class F fly ash. The highest unconfined compressive strength was obtained from specimens containing 1.7% $CaCl_2$ + 10% fly ash and it had higher and more stable strength. The higher suction value was obtained from the same mix design samples (1.7% $CaCl_2$ + 10% class F fly ash).

Sharma & Kumar (2015) used RHA and RBI grade 81 in combination with clay and after obtaining the results by performing various tests like UCS, CBR, atterberg's limits etc., they concluded that optimum mix was found to be 86 % clay, 10 % RHA and 4 % RBI with the help of consistency limit tests and compaction tests. They also found that comparatively with clay optimum mix shows increased in percentage that is the CBR value of optimum mix increases in elastic

Bushman et al (2015) calcium chloride has been used as a dust suppressant, but it is also referred to as a stabilizer because of its ability to alter material properties such as strength, compressibility and permeability. Essentially, the function of this chemical is to agglomerate fine particles and bind them together at a relative humidity of 95%, solid CaCl2 can absorb 16,6 times its weight of water. Even in a relatively low humidity environment of 30%, it can absorb almost to its own weight water . in addition, calcium chloride dissociates into Ca^{2+} ions in the process of water which lead to ion exchange reactions with Na^{+} and K^{+} ions initially adsorbed on the clay particle surface.

3. Materials

3.1 SOIL

Source of soil

The soil was brought to lab in bags and soil was dried in oven for one day followed by pulverization. Soil was pulverized to pass the soil through 4.75mm size sieve and stored as such there is least chances of absorption of water by soil. Sieve analysis tests were conducted on soil to find out the soil classification and according to the soil results soil can be classified as CI (intermediate compressible clayey soil). The Engineering properties of the soil are given in

Table no. 1 Properties of soil used in the study

S.No.	Properties	Result
1.	Liquid limit (%)	46
2.	Plastic limit (%)	24
3.	Plasticity Index (%)	22
4.	Specific Gravity	2.65
5.	Maximum Dry Density (gm/cc)	1.92
6.	Optimum Moisture Content (%)	15.10
7.	Soil Classification	CI (Intermediate Compressive Clay)
8.	CBR (%)	3
9.	UCS ($kN/m^{2)}$	82.6

3.2 CALCIUM CHLORIDE ($CaCl_2$)

Source of CALCIUM CHLORIDE ($CaCl_2$)

Calcium chloride can be used for numerous purposes at different concentrations depending on its use. It is an important calcium salt that has many household and industrial applications.

The chemical formula of calcium chloride is CaCl2 and its molar mass is 110.98g/mol. It is an iconic compound consisting of calcium cation (Ca^{2+}) and two chlorine anions (Cl^-). The bivalent calcium atom forms an iconic bond with two chlorine atoms. This research used its highest percentage calcium chloride products

Table 2: Physical properties of CALCIUM CHLORIDE ($CaCl_2$)

S No.	Properties	Value
1	Form	A white odorless granule or flake
2	Density	2.15 g/Ml
3	pH	6.5 – 10
4	Melting point	782^0C
5	Boiling point	1600^0C
6	Loss on drying	10 %

Table 3: Chemcial properties of CALCIUM CHLORIDE ($Cacl_2$)

S No.	Composition	Value (%)
1	Calcium (Ca)	94
2	Alkali chlorides (as NaCl)	3
3	Total magnesium (as Mgcl2)	0.1
4	Other impurities (not water)	1
5	Iron (Fe)	15 ppm

3.3 RICE HUSK ASH

Source of RICE HUSK ASH

RHA used in this investigation was purchased from KGR Agro Fusions (p) Limited, Ludhiana, (India). Rice husk ash was transported in polythene bags to laboratory. RHA was dried for 24 hoursand passed through 150-micron sieve after that it was stored in cool and dry place in polythene bags.

Table 4:- Chemical Composition of Rice Husk Ash

Sr. No.	Constituent	%age
1	Silica (SiO_2)	85 – 90
2	Alumina (Al_2)	2.5 – 2.6
3	Carbon (C)	2.2 -2.3
4	Calcium oxide (CaO)	1.55 – 1.6
5	Magnesium oxide (MgO)	0.5 -0.55
6	Potassium oxide (K_2O)	0.4 -0.45
7	Ferric oxide (Fe_2O_3)	0.20

4. EXPERIMENTAL RESULTS

4.1 STANDARD PROCTOR TEST

Table no. 5: Results of OMC and MDD for mix proportions of Clayey Soil with $CaCl_2$ and RHA

S.NO.	PROPORTION (CS : RHA : $CaCl_2$)	MDD (g/cm^3)	OMC (%)
1.	83 : 16 : 1	1.83	13.8
2.	81 : 16: 3	1.8	14.3
3.	79 : 16 : 5	1.76	15.1
4	77: 16 : 7	1.78	15.6

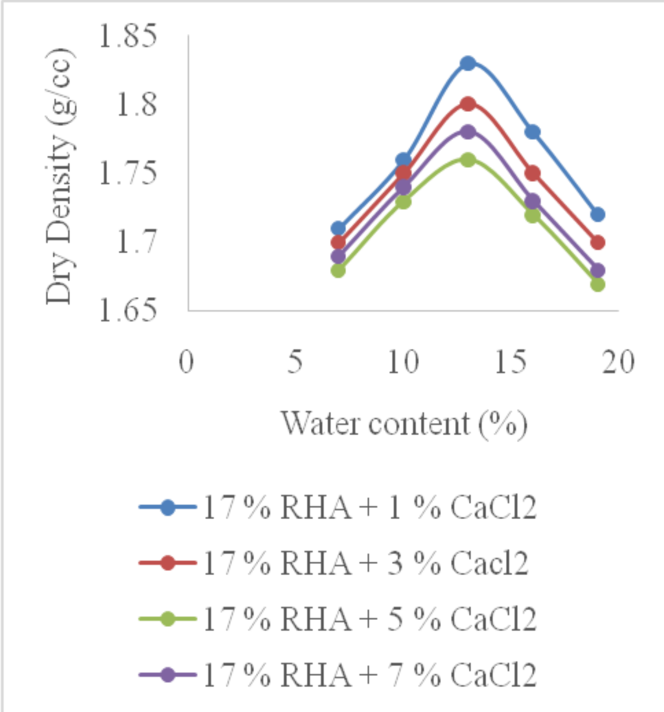

Fig:-1 Combine graph b/w MDD and OMC of Clayey Soil with $CaCl_2$ and RHA of different proportions

Table 6: Results of UCS of Clayey Soil with $CaCl_2$ and RHA

CS : RHA : $CaCl_2$	Curing Period (Days)	UCS (kN/m^2)
100 : 00 : 00	7	82.6
83 : 16 : 01	7	169.7
81 : 16 : 03	7	201.5
79 : 16 : 05	7	231.2
77 : 16 : 07	7	215.6

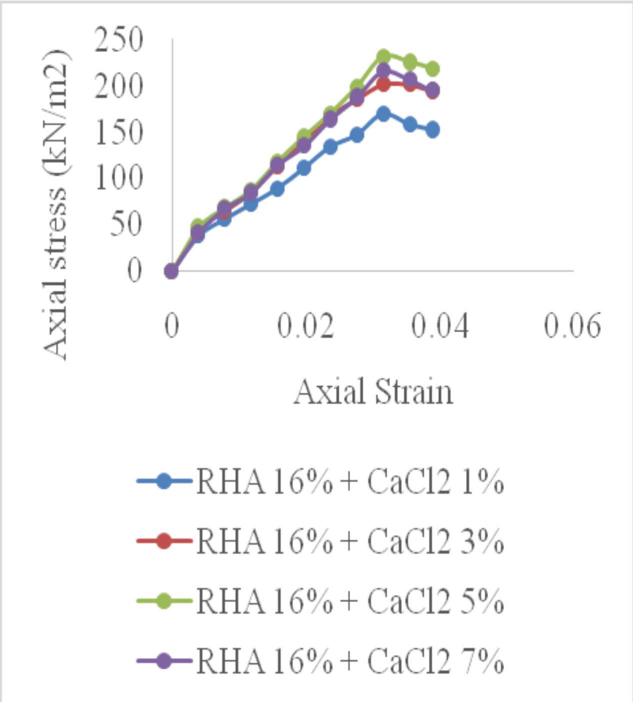

Fig:-2 Combine graph b/w UCS Values of Clayey Soil with $CaCl_2$ and RHA of different proportions

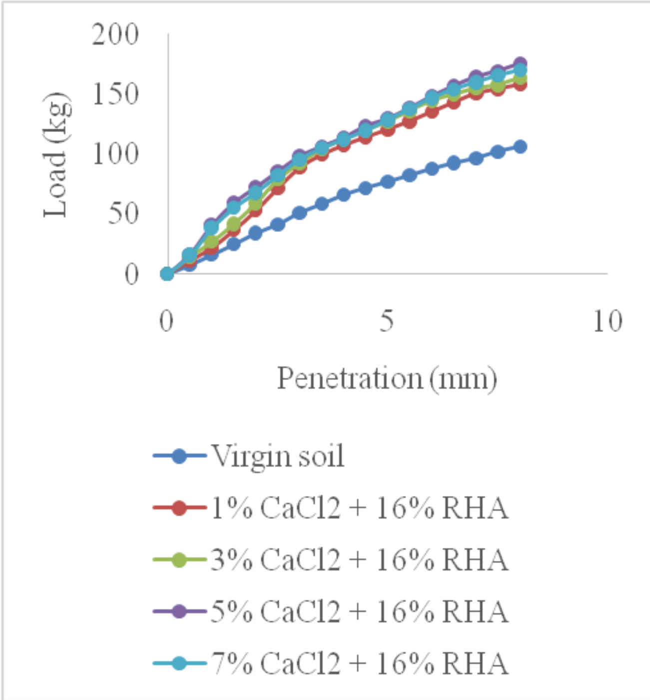

Fig:-3 Combine graph b/w CBR Values of Clayey Soil with $CaCl_2$ and RHA of different proportions

Table 7: Results of CBR of Clayey Soil with $CaCl_2$ and RHA

Mix proportion (CS:RHA:CaCl2)	CBR (%)
83 : 16 : 1	5.2
81 : 16 : 3	5.7
79 : 16 : 5	6.2
77 : 16 : 7	5.9

5. DISCUSSIONS

STANDARD PROCTOR TEST:

- An increase in OMC from 11.1 % to 16.8 % anddecrease in MDD from 1.92 g/cm^3 to 1.78 g/cm^3 was observed when the percentages of RHA are used 8, 16 and 24% respectively.
- The density of RHA is lesser than as compare to clayey soil sample. So the maximum dry density is decreased and optimum moisture content is increased.
- The expansion found in OMC with increase of RHA percentage is also due to pozzolanic response of RHA with soil that need more water for completion of cation trade response.
- An increase in MDD from 1.9 g/cm^3 to 1.93g/cm^{3}and also increase in OMC from 11.4 % to 11.7 % was observed when the percentages of $CaCl_2$are used 2, 4 and 6% respectively.

- The dry density was increased to .52 % and the corresponding moisture content was also increased to 3% when 5% of $CaCl_2$ was added in the clayey soil. This behavior of the soil may be attributed to the non-plastic behavior of $CaCl_2$ added in the highly plastic clay soil, facilitating the compaction at lower OMC and resulting in higher corresponding maximum dry density.
- With RHA kept constant at 16%, MDD decreases with an addition of $CaCl_2$ in clayey soil. The reason behind such behavior is RHA is lighter in weight and it has high water absorption properties because of the presence of silica oxide and hence OMC increases with the increase of RHA content.

CBR TEST:

- The UCS tests were conducted on the soil sample with 3 varying percentages of $CaCl_2$ (2,4,6%). The maximum value of UCS was obtained as **131.2kN/m^2** at 4% $CaCl_2$. The UCS value showed an increase from 82.6 Kn/m^2 to 131.2kN/m^2. The increase in the UCS value was attributed to the gradual formation of cementitious compounds (calcium silica hydrate) due to the reaction between the calcium carbonate present in the $CaCl_2$, soil and water.
- The UCS value of virgin soil is 82.6kN/m^2 and it starts to increase with the addition of RHA. The optimum value of UCS comes out to be 141.5 Kn/m^2 with 16 % RHA, after that the value starts to decrease. This improvement is because of increases the cementation property of soil.
- The UCS values of virgin soil also improve considerably with the combination of RHA 16% and $CaCl_2$ 5%. The value increases from 82.6kN/m^2 to 231.2 Kn/m^2.
- The main reason for these changes is the pozzolanic reaction of lime present in the Calcium chloride, silica in Rice husk ash and the alumina content present in the clayey soil. At the same time, increase in strength is possible up to an optimum value but after that, it starts decreasing. This reduction in UCS value is due to a reduction in cohesion because of the decrease in clay content present in the soil mix. The cause of this reduction is the availability of extra silica to react with insufficient amorphous alumina and lime present in the soil. The UCS value increases by 64% to untreated soil sample. Graph shows the variation of UCS with different percentages of Calcium chloride and Rice husk ash.

UCS TEST:

- we got optimum CBR value at 16% addition of RHA that is there is increment of 35 % with respect to base sample and 26 % with respect to the previous proportion which is 8 %, after that the percentage of CBR value starts to decrease.
- With the addition of Calcium chloride starting from 2% to 4%, there is increase in CBR value (3.2 to 3.7) which is 13.5 % while 19 % with respect to base sample of soil, as shown in graph. But after 4% $CaCl_2$, there is decrement of 5% in CBR value when 6% $CaCl_2$ is added. That means 4% is the optimum content of calcium chloride used in this experiment study.
- Addition of high concentration of $CaCl_2$ (>4%) may leads to high early strength but much of this strength gain is lost over time. Even some limited data indicated that beyond 2 % addition of calcium Chloride may significantly reduce the long term strength of soil but if this high amount of $CaCl_2$ (5%) is combined with 16 % RHA leads

to high early strength with no tendency of declination of strength of soil.

- Based on the CBR test results, the value of CBR increases from 3 to 6.2 with the addition of different proportion of RHA and $CaCl_2$. The optimum value of CBR is 6.2 which is obtained by performing the CBR test by mix proportion of 16% RHA and 5% $CaCl_2$.
- This enhancement in CBR value may be because of the gradual formation of hydration compounds in the soil due to the reaction between the stabilizers and the essential particles present in the soil. This reaction produces stable calcium silicates hydrates as the calcium from calcium chloride reacts with the silicates solubilized from the RHA and clay.

6. CONCLUSIONS

Six samples containing three different contents of calcium chloride (0%,2%, 4% and 6%) with Rice husk ash (8%, 16%% and 24%) were tested at 7 cure days to verify the effectiveness and optimum ratio of calcium chloride and Rice husk ash in soil stabilization. Following determination of Atterberg's limits, optimum moisture content, moisture content variation depending on mix design with cure time and unconfined compression strength were determined according to ASTM method.

On the basis of above experimental results and discussions, the following conclusions can be drawn

[1] In this study, a series of standard Proctor test, unconfined compression strength test and the CBR test was carried out to calibrate the effect of two chemical additives namely Calcium chloride and RHA on the clayey soil sample. The results showed that Calcium chloride and RHA could improve the UCS value, Dry density and CBR Percentage of clayey soil sample.

[2] The different percentages of $CaCl_2$ and RHA used in this study were 02%, 04%, & 06% and 8%, 16%and 24%. Finally, the value of RHA was fixed to 16% with variation of $CaCl_2$ (01%, 03%, 05% and 07%) to clayey soil.

[3] Addition of $CaCl_2$ and RHA with clayey soil decreases maximum dry density and increases the optimum moisture content of the soil sample.

[4] . The addition of the fixed quantity of RHA 16% with changing the content of $CaCl_2$increases the value of optimum moisture content and decreases the value of maximum dry density.

[5] The optimum value of RHA used in this research is 16% because the maximum value of UCS was found at 16% RHA.

[6] The UCS value increases with an increase of $CaCl_2$ content along with a fixed quantity of RHA. The maximum value of UCS was found at 05% $CaCl_2$ and 16% RHA.Further increase of $CaCl_2$ content in soil would decrease the UCS value.

[7] Based on the CBR test results, the value of CBR increases from 3 to 6.2.

[8] The optimum value of California Bearing Ratio was found at 05% $CaCl_2$ and 16% RHA.

[9] No more than 3 % calcium chloride is recommended to obtain high early strength but if long-term strength is also required, then 5 % calcium chloride with 16 % Rice husk ash should be considered.

[10] Hence, the addition of $CaCl_2$ and Rice Husk Ash makes the soil mixes durable, economical and effective for soil stabilization process if these two materials are easily available near to the site.

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