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AN EXPERIMENTAL STUDY ON STABILIZATION OF CLAYEY SOIL BY USING CALCIUM CARBIDE RESIDUE AND FLY ASH

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ABSTRACT

The experimental study was done to strengthen the clayey soil properties by using waste material of calcium carbide, which is responsible for negative effect to the environment. In the study, waste products such as Calcium Carbide Residue (CCR) and Fly Ash (which is also called by-product of acetylene gas factories generated from power plant were added in a clayey soil sample in different varying ratios 0%,10%15%20%30% used. The effect of calcium carbide residue and fly ash on geotechnical characteristic of clayey soil was determined by using pycnometer method for testing specific gravity, oven dry method for determining moisture content, Liquid Limit, Plastic Limit, Plasticity Index, Modified proctor test, California bearing ratio and Unconfined compressive strength were performed as per Indian standards. As compare to virgin soil the UCS and CBR values increased with increase in dose of calcium carbide residue 10% and beyond this it decreased. Therefore, required dose of Calcium Carbide Residue (CCR) 10% and Fly Ash 10% by weight of soil. The total weight 20% (CCR&FA) had been found to greater strength.

Keywords— Calcium Carbide Residue (CCR), Fly Ash (FA), Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (I_P), California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS), Maximum dry density (MDD)

I. INTRODUCTION

Various techniques can be used for improving the engineering properties of clayey soil, known as soil stabilization. Stabilization of soil is the process of stabilize the soil by varying the properties of soil to improve its engineering properties, so that it can be used in various works of civil engineering. In this modern era where population and urbanization is at its peak and rapid construction of bridges, roads, buildings etc. The soil over which the construction is to be carried out should have enough strength to carry the design load, so that it can bear the load of the structure. This problem mainly occurs when construction is to be constructed on clayey soil. This soil is considered as very strength material from civil engineering point of view for the construction of highways, bridges, embenkments etc. Stabilization is going to full fill the needs and requirements of the growing population year by year, It becomes very important task of knowing the importance of the soil strength parameters so as to start the any construction project work.soil strength parameters are often modified in positive manner to make it suitable for bear the designed load.Soil is the basic foundation for any civil engineering construction. It should bear the the loads without failure. In some area, soil may be not able to resist the oncoming loads of the structure. In such cases, stabilization of soil is needed. There is various methods are available for soil stabilization. Stabilization of soil is a general process for any chemical, physical, biological, or combined method of changing a natural soil and strengthen to meet an engineering purpose.Most of the time, some of the methods like chemical stabilization, lime stabilization etc. adversely affects the chemical composition of the soil. In this project, different proportions of fly ash and calcium carbide residue has been mixed with the available clayey soil and the modified strength are to be compared with the Standard results. To determine the characteristics of engineering properties such as atterbergs limits i.e. liquid limit, plastic limit, optimum moisture Content and maximum dry density, california bearing ratio by conducting CBR test is done. Improvement in the behavior of soil by adding Calcium Carbide Residue and Fly Ash is the very suitable method as these waste materials give rise to ecological hazards. Soil for testing purpose is collected from Baliapur (sindri) , Jharkhand. Approximately 25 to 30 kg of soil sample is collected. Further the sample was kept for drying. Every type of soil has its own strength and show different properties when subjected to load, some soils are best for construction while some are not feasible, because of their poor behaviour, when the load is being subjected. The stabilization is to increase the properties of clayey soil like low bearing capacity low shear strength, volumetric shrinkage and high moisture susceptibility. Improvement in the behaviour of soil by adding Calcium Carbide Residue and Fly Ash in a definite quantity.Improvements in the unconfined compressive strength and California bearing ratio ensure the enhancement of the clayey soil same was observed in this study.

II. OBJECTIVE OF THE STUDY

The main aim of this study is to observe the ability to stabilize a clayey soil to assure use as a sub base, road, and embankments fills with economical.

a. To examine the soil property which is improved by addition of (CCR and FA).
b. To find effect of stabilization in engineering properties.
c. To analyse the combined effect as well as individual effect of the varying proportion of calcium carbide residue and Fly Ash in soil strength at various water contents.

III. LITERATURE REVIEW

Horpibulsuk S. et al. (2013) have analyzed the improvement in the strength of stabilized CCR and FA clay. A very high $Ca(OH)_2$ content of 76.7% is found in CCR. A soil that contains a high percentage of natural pozzolanic material can be improved by using it alone. They also mentioned that if the natural pozzolanic material is completely absorbed by the input CCR, CCR and FA can be used together for higher strength requirements.

Kampala A. et al. (2013) have focused their study to have a basic idea about the engineering properties of stabilized CCR soil in its recycled form. Scanning electron microscopic (SEM) images manifest that the recycled form of stabilized CCR soil grains is bigger than the CCR and clay particles. The reason for this is the attached pozzolanic products with the recycled stabilized CCR soil. The large grains of the recycled CCR stabilized clay reduces linear shrinkage and free swell ratio. Since the hard pozzolanic products resist compaction, the recycled CCR stabilized clay has a lower unit weight compared to the CCR stabilized clay for the same amount of compaction energy and CCR content.

Vichan S. et al. (2013) have conducted experimental work to investigate the effects of blending CCR and biomass ash (BA) which acts as a stabilizing chemical additive, and leads to a pozzolanic reaction. Their research work suggests that calcium hydroxide $Ca(OH)_2$ was formed when CCR dissolves in water. Pozzolanic products were obtained by dissolving the amorphous Si from BA in a higher pH solution (pH=12.6). It has also been observed that the combined effects of CCR and BA on clay strength development were observed when the binder content reached 30% of the dry soil weight.

Raut J. et al. (2014) have tried to examine the property enhancement of expansive soil by varying the percentage of fly ash and murrum. With an increase in the percentage of fly ash and murrum, the MDD and unconfined compressive strength is found to be increasing till a certain limit and thereafter their value decreases. They have reported that the optimal combination for property enhancement of clay is attained by mixing 5% of fly ash and 7.5 % of murrum with it.

Jiang N. et al. (2015) have compared the stabilized quicklime soil by conducting a multi-scale laboratory investigation focusing on the several properties viz., mechanical, physical and also microstructural of stabilized CCR clayey soils. It was observed that within the initial 28d, stabilized CCR soil has significantly lower pore volume as compared to stabilized quicklime soil. However, this difference in pore volume is almost negligible at 120d. A converse correlation was noticed between the stabilized soil and a larger volume of pore in the soil. At the initial stage, the vital contributor to the rapid and complete development of flocculation and agglomeration of soil particles are high pH value, significant specific area and fine size particle of CCR soil when compared to quicklime.

Du Y. et al. (2016) worked on finding the mechanical properties of CCR stabilized soft clayey soil which is utilized as a subgrade course material for the highways. In an adjacent field section, Quicklime was used as a control binder to compare its performance with CCR.

Latifi N. et al. (2018) have focused their study to examine CCR practicability to stabilize clay. Natural pozzolanic materials in clay can react with CCR following pozzolanic reactions. Tests indicated that a significant improvement in compressibility and strength has been observed utilizing CCR. The highest strength improvements in UCS tests were obtained with CCR dosages of 9% and 12% for bentonite and kaolin, respectively. After 28 and 90 days of curing, the UCS of the 9% added CCR tested bentonite increased by 4.7 and 6.8 times those of untreated soil respectively. Upon curing CCR-stabilized kaolin for 28 and 90 days, the UCS improved by 3.8 and 5.8 times, respectively.

Jafer H et al. (2018) have successfully figured out the impact of palm oil fuel ash (POFA) pozzolanic reactivity on the soft soil engineering properties, stabilized with high calcium fly ash (HCFA). According to UCS and Atterberg limits the HCFA and POFA combination leads to higher compressive strength and lower plasticity index (PI) compared to the HCFA-based treated soil alone.

Murmu A. et al. (2018) have performed certain experiments by differing the content of fly ash in the range of 5% to 20% and handing the samples at a considerably least concentrated 5M NaOH solution. A laboratory test was conducted to determine the California bearing ratio, unconfined compressive strength, resilience modulus, and California bearing ratio of stabilized samples. The addition of fly ash from 0% to 20% has slightly decreased the liquid limit and increased the plastic limit.

Ayodele F. et al. (2022) have tried to find out the influence of binary blends of Rice Husk Ash (RHA) and Calcium Carbide Residue (CCR) on lateritic soil engineering properties. A noticeable improvement in soil consistency was noted. At different dosages of optimum CCR: RHA, the California Bearing Ratio improved for soil strength up to 6%. Overall, the stabilized soil strength as measured by UCS improved as additives were added. These additives improve the soil's ability to resist erosion. As the additive content of the soil increased, its plasticity decreased.

IV. RESEARCH METHODOLOGY

I. Materials Used

Clay soil: The most important Type of soil in engineering point of view. Having low bearing and shearing strength and less feasible to construct the heavy structures. Mainly are finely grained particles of size less than 0.002 bearing a property of cohesion plastic type soils. Clayey soils are very important in geotechnical engineering because of their complex behavior. It must be stabilized to carry a load to be constructed on it.

Fly Ash: The residues formed in combustion in power plants, and consists of the very fine particles that rise with the flue gases.Platicity index of fly ash treated soil decreases mainly due to increase in the plastic limit.Liquid limit may increase or decrease depending upon the type of soil. When the fly ash is added to the clayey soil, the California bearing ratio and unconfined compressive strength of soil will be increased and thus improve the strength and compressibility of the soil. compression test as per IS 2720 (part 10) was performed on the samples after 7, 14 and 28 days of curing. All specimens were prepared at the same density and water content by means of proctor's compaction to control the effect of density and moisture on the strength.

Calcium carbide residue: It is the by-product of the acetylene production process that mainly contains calcium hydroxide, Ca (OH)2.CCR after being sun dried for a few days, the slurry state is changed to dry state.The dry CCR was oven dried at 100 degree Celsius for 24 hour.CCR react with FA and produce a cementitious property.The study of soil stabilization with a mixture of (CCR) and pozzolanic materials is an engineering, economic, and environmental challenge for geotechnical engineers and researchers. This paper investigates the possibility of solely utilizing (CCR) with fly ash to stabilize problematic weak clayey soils.It is the by-product of acetylene gas production process, and is in slurry form that mostly has calcium hydroxide (Ca (OH) 2) along with CaCO3, SiO2, and other metal oxides. Acetylene gas factories and (PVC) chemical Plants produce (CCR) in huge quantities and cause hazards to the environment due to their alkalinity. It has high calcium content. With the increase in (CCR) content, the maximum dry density decreases and optimum moisture Content increases.

Table 1: Properties of natural Soil sample

Properties	Results
Specific Gravity	2.73
Natural Moisture Content (%)	13.83
Maximum Dry Density (MDD) KN/m^3	15.11
Liquid Limit (%)	35.51
Plastic Limit (%)	28.33
Plasticity Index	7.18
UCS (kgf/cm^2)	1.98
CBR (%)	5.52

Table 2: Chemical Composition of Calcium Carbide Residue (CCR)

Chemical compound	Value in %
SiO_2	4.6
TiO_2	0.009
Al_2O_3	0.49
Fe_2O_3	0.10
MnO	0.002
MgO	0.22
CaO	90
Na_2O	0.06
K_2O	0.002

II. Methodology

Two various phases of the experimental study were carried out. Engineering tests were performed on a soil sample and compared with after addition of calcium carbide residue and fly ash. Varying percentages of CCR and FA were (0, 10, 15, 20, and 30%).Both of these stages' engineering tests were carried out in accordance with Indian standard codes.

The following table represents the test conducted along with the IS codes:

Table 3: Engineering tests along with Indian Standard Codes

Test Name	Indian Standard Codes (IS Codes)
Wet Sieve Analysis	IS 2720(Part 4)-1985
Liquid Limit Test	IS 2720(Part 5)-1985
Plastic Limit Test	IS 2720(Part 5)-1985
Modified proctor test	IS 2720(Part 7)-1980
Unconfined Compression Test	IS 2720(Part 10)-1991
California Bearing Ratio	IS 2720(Part 16)-1987

i. **Sieve Analysis [IS 2720(Part 4)-1985]:** This code is used to evaluate particle size distribution or gradation of a granular material.

ii. **Liquid Limit Test [IS 2720(part 5)-1985]:** Defined as the moisture content at which 25 blows or drops in standard liquid limit apparatus will just close a groove of standardized dimensions cut in the sample by the grooving tool by a specific amount.

iii. **Modified Proctor Test [IS 2720(part 7):1980]:** It is used to determine the compaction of different types of soil and the properties of soil with a change in moisture content; and the relationship between Dry Density and Moisture Content.

iv. **Unconfined compression Test [IS 2720 (part 10)-1991]:** It is the most common, and fastest method for soil shear testing. The unconfined test is used for saturated and cohesive soils.

v. **Plastic Limit Test [IS 2720 (part 5)-1985]:** The test is also known as the lower plastic limit, is the water content at which a soil changes from the plastic state to a semisolid state.

vi. **California Bearing Ratio (CBR) test [IS 2720 (Part 16) - 1987**]: The California bearing ratio test is a penetration test used to evaluate the subgrade strength of roads & pavements. The tests results are used with the empirical curves to determine the pavement thickness and its component layers.

V. RESULTS AND DISCUSSIONS

Table 4: Properties of natural soil replaced with 20 % of CCR+FA

TEST	PARAMETERS	DISCRIPTIONS
Atterberg's Limit	Liquid Limit	20.03
	Plastic Limit	14.76
	Plasticity Index	5.27
Unconfined Compression Test	UCS Value	2.05 kgf /cm^2
California Bearing Ratio (CBR)	CBR Value	6.18%

VI. GRAPHICAL REPRESENTATION OF TEST RESULTS

At different percentages of calcium carbide residue and fly ash (0, 10, 15, 20, 30) were mixed properly with the clayey soil

Following bar graphs represent the comparison of various engineering tests properties:

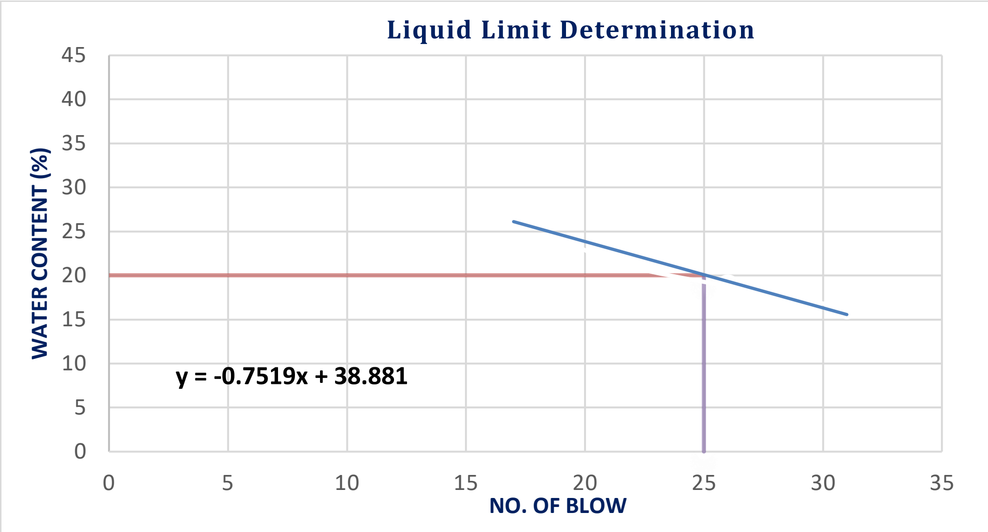

Figure 1: Liquid Limit at 20 % of CCR+FA

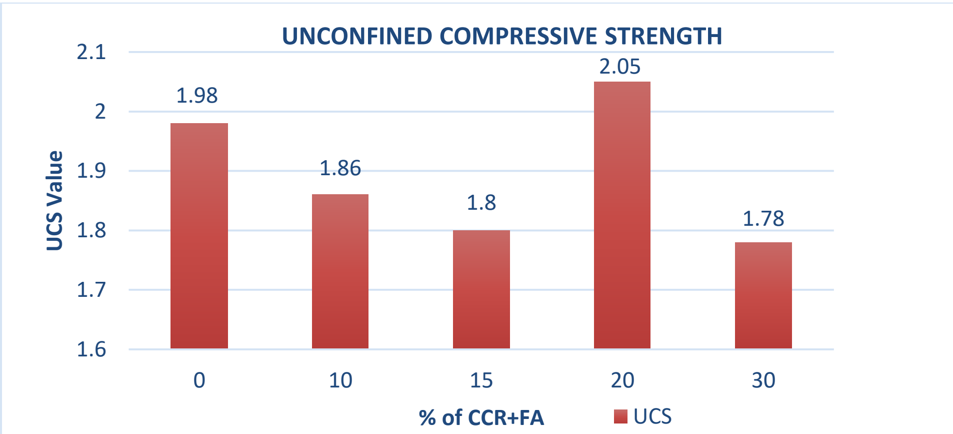

Figure 2: Unconfined compressive strength (UCS) at varying % of CCR+FA

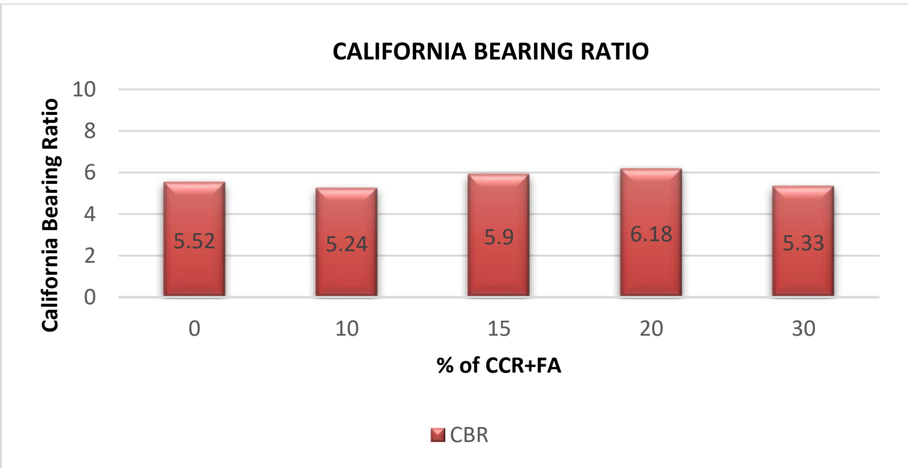

Figure 3: California bearing ratio (CBR) at varying % of CCR+FA

VII. CONCLUSION

With addition of 0% (CCR and FA) by weight of soil , the (CBR) values in unsoaked condition increased from 5.52%.With addition of (CCR) in small amounts , there is a significant increase in the (CBR) values as compared to the (FA) and also the soaked (CBR) is greater than the unsoaked (CBR) on account of curing. When 10% (CCR and FA) by weight of soil was mixed with the soil as per the optimum moisture of the soil the (CBR) values in unsoaked condition was found to decrease to 5.24% .Further with addition of 15% (CCR) and (FA) cement by weight of soil, the (CBR) values increased from 5.9%in unsoaked condition.With further (FA) and (CCR) being restricted to 20% by weight of soil , the unsoaked (CBR) will be maximum. Hence this suggests an increase of 6.16% in unsoaked CBR is having the greatest strength.

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