# A Study on the Strength Behaviour of Clayey Soil using Calcium Carbide Residue and Flyash

Jina Job
M.Tech Geotechnical Engineering,
Deparment of Civil Engineering,
Marian Engineering College,
Kazhakuttom, India

Aswathy Sasikumar
Assistant Professor,
Deparment of Civil Engineering,
Marian Engineering College,
Kazhakuttom, India

***Abstract*** **– Soil is the basic foundation for any civil engineering structure. In some cases, soils may be weak, which cannot resist the load oncoming to it. One of the most commonly availiable method for soil improvement is stabilization. The main purpose of improvement in weak soil is that the strength of clay is improved when a proper amount of cementitious materials are added. The soil improvement techniques, which are widely used nowadays, are compaction, mechanical stabilization, and adding chemical stabilizers. In this study calcium carbide residue and flyash were mixed with clayey soil to investigate the strength behaviour of the clay sample. The effect of calcium carbide residue and flyash on geotechnical characteristics of clayey soil was investigated using proctar compaction and unconfined compressive strength tests which were performed as per Indian standards.**
**Keywords: Calcium carbide residue; Engineering properties; Pozzolanic reaction; Soil stabilization.**

## I. INTRODUCTION

The purpose of my study is to understand the strength behavior of clayey soils using industrial waste products due to which the strength of weak clayey soils will be improved. The improvement technique by adding stabilizers to provide cementation bonds between soil particles has been used for several years, particularly for fine-grained soils. The examples of adding stabilizers are lime, cement and lime-fly ash, which are cementitious materials.Disposal of industrial solid wastes on land can result in unproductive land for vegetation along with possible degree of contamination of ground and surface water. Considering the cost and difficulties involved in treatment and disposal of solid wastes its reuse is one of the most environment friendly options. The need for reuse of waste materials is mainly due to environmental considerations, due to the increased scarcity of natural resources and the increasing cost of landfill in most of the countries. The improvement technique by adding stabilizers to provide cementation bonds between soil particles has been used for several years, particularly for fine-grained soils. The hydration and pozzolanic reaction process in cement-stabilized clay can be explained as follows: when water comes in contact with cement, cement hydration occurs rapidly.Thus, from an economic and environmental viewpoint, some waste materials which is rich in $Ca(OH)_2$ can be used together with pozzolanic materials, such as fly ash, biomass ash, and rich husk ash, to develop a cementitious material.

Calcium carbide residue (CCR) is a by-product of the acetylene production process that mainly contains calcium hydroxide, $Ca(OH)_2$. 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. Understanding the mechanism controlling strength development in blended CCR-stabilized clay is necessary for estimating the optimal CCR: FA ratio for different binder contents. 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. The unconfined compressive strength was used as a practical indicator to investigate strength development. Flyash is one of the most plentiful industrial waste products. It is a solid waste product created by the combustion of coal. Its appearance is generally that of light to dark grey powder.

## II. MATERIALS AND METHOLOGY

### *A.Materials*

Soil sample: The soil sample issilty clay collected from the Thonnakkal quarry, Thonnakkal, Trivandrum district, Kerala. The properties of the soil used for the study are tabulated in Table 1. Based on the Unified Soil Classification System (USCS), the soil is classified as high plasticity (CH) clay.

TABLE.I. PROPERTIES OF THONNAKKAL CLAY

| | |
|---|---|
| Natural moisture content (%) | 22.5 |
| Specific gravity | 2.5 |
| Liquid Limit (%) | 46.5 |
| Plastic Limit (%) | 28.9 |
| Shrinkage Limit (%) | 27.8 |
| Plasticity Index (%) | 27.1 |
| Maximum dry density (g/cc) | 1.4 |
| Optimum moisture content (%) | 38.6 |
| Unconfined compressive strength (KPa) | 103 |
| Percentage of clay (%) | 58 |
| Percentage of silt (%) | 20.5 |
| Percentage of sand (%) | 21.5 |

**Calcium carbide residue:** Calcium carbide residue is a by-product, which is obtained from the acetylene gas production. Most of the residue has been sent to landfills, causing many environmental problems such as dust and high alkalinity of the disposal area. In the present study it was collected from Ajay acetylene private limited, Ernakulum district, Kerala. The primary chemical composition of calcium carbide residue in slurry is calcium hydroxide $Ca(OH)_2$. The secondary compositions are calcium carbonate ($CaCO_3$), Silica oxide ($SiO_2$) and other metal oxides.

**Flyash:** It is one of the residues formed in combustion, and consists of the fine particles that rise with the flue gases. It is also known as flue-ash. Fly ash is captured from the chimneys of coal-fired power plants. It mainly consists of $SiO_2$ and $Al_2O_3$due to which it is pozzolanic in nature. The mineralogical composition, fine particle size and amorphous character of flyash shows that it is generally pozzolanic and in some cases self cementitious.

*B.Methodology*

**Index properties:** In this study, the collected calcium carbide residues were air-dried to reduce the water content and then were ground before adding to the soils. The soil samples collected were air-dried for a minimum of three days. The index tests on soil samples and the CCR stabilized samples were carried out immediately after thorough mixing. The index tests were carried out as per IS 2720 (part 5).

**Compaction:**The compaction of the natural soil samples and the CCR stabilized soils were carried out using Proctar's cylindrical mould with removable collar and base plate and a rammer of 25 Kg using a 30.5 cm free drop according to IS 2720 (part 7). At least five compaction points were generated. The compaction characteristics of soil sample 1 (optimum moisture content, OMC, and maximum dry unit weight, $\gamma_{dmax}$) were obtained as 28.6% and 1.4g/cc respectively and that of soil sample 2 were obtained as 18.18% and 1.694g/cc respectively. Having obtained the compaction curve, the air-dried soils were thoroughly mixed with various contents of CCR (0-30%). These compacted samples determine the role of CCR on strength development and the zone of improvement. Compaction was done for 5 and 10 percentages of binder. These binders are selected as a representative samples of active and inert zones. The CCR: FA ratios, by weight varying in these binders are 100:0, 90:10,30:70,50:50 and 30:70.

**Unconfined compressive strength:** The strength of the blended CCR (CCR and FA) stabilized clays was investigated using 5 and 10% binder (CCR and FA). These binder contents are considered representative of the active and inert improvement zones, respectively (the CCR improvement zones are presented in the subsequent section). The CCR: FA ratios, by weight, were 100:0, 90:10, 30:70, 50:50 and 70:30. The unconfined 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 Proctar's compaction to control the effect of density and moisture on the strength.

## II. RESULTS AND DISCUSSIONS

### *A. Quarry Sand-Soil Composite*

**Index properties:**Fig.1 shows the change in index properties of CCR- stabilized soil samples. It is observed that the plastic limit (PL) increases while the liquid limit (LL) decreases which results in decrease in plasticity index (PI). This decrease in PI shows the flocculation of clay particles, which is caused due to the adsorption of $Ca^{2+}$ions from the cation exchange process. When the CCR content is greater than 7%, it is seen that the change plasticity index is reduced. It shows a constant variation. Thus it can be concluded that the maximum adsorption capacity of calcium ions by this soil sample occurs at 7% CCR. This point can thus be termed as the "CCR fixation point". The PI reduction shows the flocculation and the coagulation aggregation of the clay particles, which are caused by the absorption of $Ca^{2+}$ions. The input of CCR causes the cation exchange and soil flocculation, which results in the reduction of plasticity index of the soil. The reduction in plasticity index is constant when the CCR content is greater than the CCR fixation point because the compaction characteristics (OMC and $\gamma_{dmax}$) of the silty clay are dependent upon the plasticity index. The compaction characteristics of the stabilized clay change with the input of CCR up to the CCR fixation point.

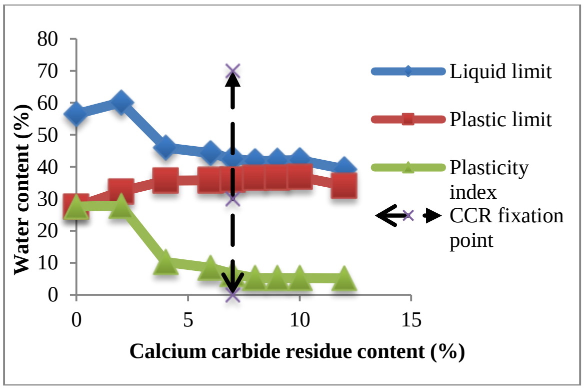


Fig. 1. Index properties of stabilized sample 1 at different CCR contents

**Compaction:** Fig.2 shows the compaction curves for the CCR-stabilized samples for different CCR contents. The maximum dry unit weight, $\gamma_{dmax}$ decreases with increasing CCR content [Fig.2] because of its lower specific gravity. This decrease in $\gamma_{dmax}$is associated with an increase in optimum moisture content (OMC). As CCR content increases, the water-sensitivity of the CCR-stabilized clay decreases, i.e., a large increase in water content causes only a minor change in dry unit weight. The maximum strengths of all the stabilized clay samples occur approximately at their OMC.

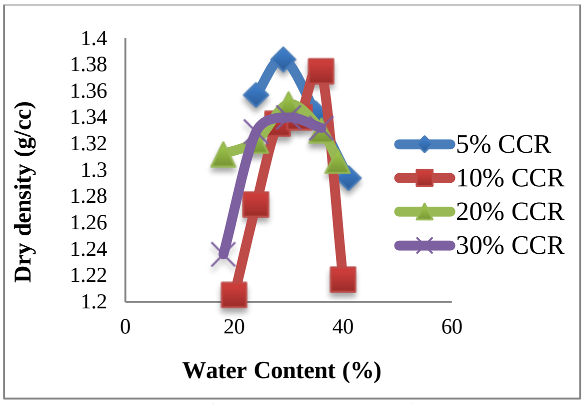


Fig.2.Compaction curves of varying percentages of CCR with soil sample

Figs.3 and 4 presents typical compaction curves of the blended, CCR- stabilized clay with various CCR: FA ratios of soil sample. The maximum dry unit weight of the blended CCR-stabilized samples increases with increasing FA content (decreasing CCR content). This is because FA has a slightly higher specific gravity than CCR and therefore causes an increase in the specific gravity of the binder (CCR+FA). The spherical shape of the FA is also the main contributor to the compaction efficiency. It aids soil and CCR particles to slip over each other and into a densely packed state. However, all the blended CCR-stabilized soil samples possess a lower maximum dry unit weight than the compacted clay sample because of its lower specific gravity.

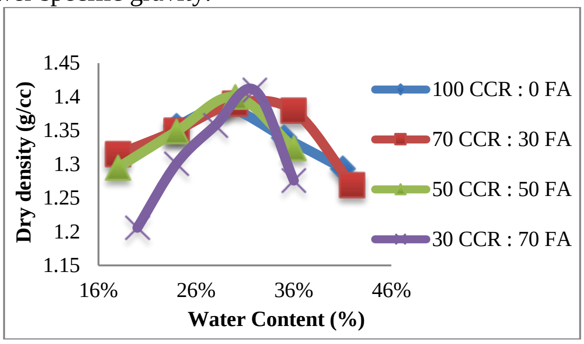


Fig.3 Compaction curves of blended CCR-stabilized sample (5% Binder)

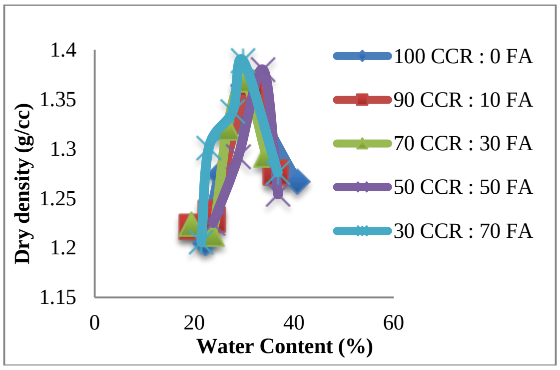


Fig.4 Compaction curves of blended CCR- Stabilized sample 1 (10% Binder)

**Unconfined Compressive strength:** The strength curve of CCR stabilized sample with varying percentages of CCR at its optimum moisture content is shown in Fig.5 after 28 days of curing. The strength development of the stabilized soil sample is classified into three zones, which is shown in fig.5. As the CCR content increases, the strength significantly increases. This zone is designated as the active zone. Beyond this zone, the strength development slows down. The incremental gradient becomes nearly zero and does not show any further significant improvement. This zone is known as the inert zone (CCR content = 7-15%). The strength decrease appears when the CCR content is higher than 15%. This zone is referred as the deterioration zone. From these results, the optimal CCR content for soil is obtained at 7%, which is known as theCCR fixation point of the soil sample.

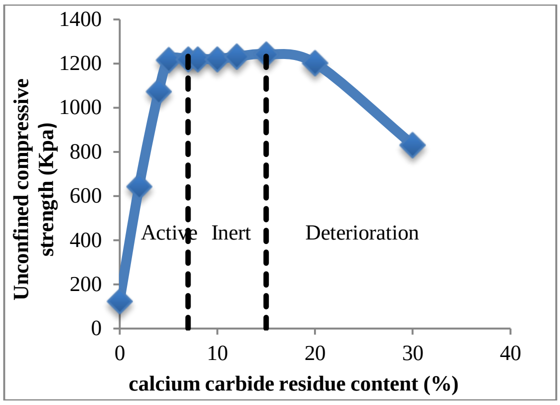


Fig. 5. Strength curve of CCR stabilized clay

Figs. 6 and 7illustrate the role of the input of FA (as a CCR replacement) on strength development in the blended CCR-stabilized sample 1 with 5 and 10% binder. For the same 5% binder (Fig.18), the strength of the blended CCR-stabilized
clay is reduced with the input of FA (CCR replacement) and the CCR: FA ratio of 100: 0 demonstrates the highest strength for all curing times tested. The same is not true for stabilization with 10% binder (in excess of the CCR fixation point). The CCR: FA ratio of 70:30 exhibits the highest strength, and CCR: FA ratio of 90:10 and 80:20 shows higher strength than the CCR: FA ratio of 100:0 (no FA). Itshows that replacement of CCR with less than 30% FA increases the dry unit weight of the stabilized samples. The strength improvement occurs irrespective of the dry unit weight because the strength is governed by the growth of the cementitious products. The CCR replacement insignificantly influences strength development when the CCR content is less than the CCR fixation point (7%), as shown in Fig.8. The role of FA becomes relevant when the CCR content is greater than the CCR fixation point. For field applications from strength and environmental viewpoints, only CCR is recommended for low strength requirements with the limit (maximum) strength at the CCR fixation point. To achieve a very high strength, both CCR and FA in a suitable ratio are recommended.

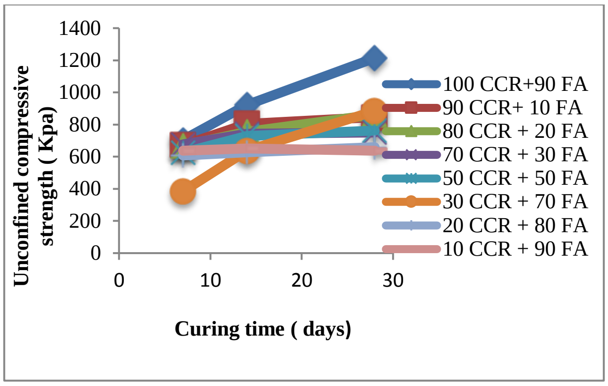


Fig. 6. Strength development in blended CCR stablized soilsample at OMC (5% Binder) for different CCR: FA ratios

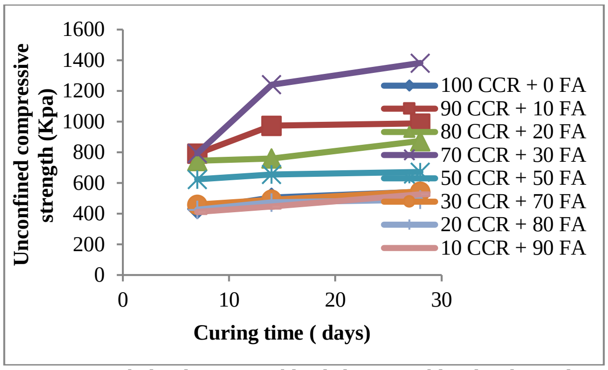


Fig. 7. Strength development in blended CCR-stablized soil sample at OMC (10% Binder) for different CCR: FA

## IV. CONCLUSION

This study reveals that the input of CCR reduces the maximum dry density of soil. As the specific gravity of CCR is lesser than that of the soil, there is a reduction of the maximum dry unit weight and an increase in optimum moisture content. Flyash increases the maximum dry density of the blended CCR-stabilized soils, which indicates a packing effect, and this packing effect consequently improves strength development, pozzolanic reaction plays a main role on strength development as the increase of the curing time. It is seen that the maximum strength in 10 percentage binder is obtained when the CCR: FA ratio is 70:30 in this soil sample. The beneficial utilization of flyash and calcium carbide residue presents an opportunity to achieve the susutainable utilization of industrial wastes.

## REFERENCES

[1] Horpibulsuk,S.,Kampala,A.,Prongmanee,N.,Chinkulkiniwat,A.(2014 ).“Influence of wet-dry cycles on compressive strength of calcium carbide residue-fly ash stabilized clay.” Journal of Materials in Civil Engineering,26(4),633-743.

[2] Horpibulsuk, S., Phetchuay, C.(2013).” Strength development in silty clay stabilized with calcium carbide residue and flyash.” Journal of Materials in Civil Engineering 53(4), 477- 486.

[3] Horpibulsuk, S., Phetchuay, C. (2012). “Soil Stabilization by Calcium Carbide Residue and Fly Ash.”Journal of materials in civil engineering, 24(2), 184-193.

[4] Kumrawat, N.,and Ahirwar, S., K. (2014), “A performance analysis of black cotton soil treated with calcium carbide residue and stone dust “International Journal of Engineering research and science & Technology, 3(4), 2319-5991.

[5] Kumrawat, N.,and Ahirwar, S., K. (2014), “Experimental study & analysis of black cotton soil with CCR & BA ”International journal of sciences and management, 4(3),2277-5528.

[6] Sanjay,B.,and Vikash,A., (2012). “A comparative study strength improvement and CBR properties of NIT hostel area soil by using calcium carbide residue and flyash.” National Institute of Technology, Rourkela.,1-83.