Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 12; April-June, 2015 pp. 1039-1044

http://www.krishisanskriti.org/jbaer.html

Soil Stabilization Using Calcium Carbide Residue and Coconut Shell Ash

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Abstract—*Calcium rich and silica rich waste materials are abundantly available in many countries. These wastes ended in a waste dump there by polluting environment and endangering the lives of the people living within the vicinity. Calcium carbide residue CCR and coconut shell ash CSA are such wastes produce as result of industrial and agricultural activities. Utilizing these wastes for stabilization purposes may result in providing a product with adequate strength for construction purposes. In this research, CCR and CSA were employed in stabilizing CI and CH soils, CCR was fixed at 4% and 6% in CI and CH respectively using index properties tests and then CSA was varied (i.e. 4, 9, 14, & 19%). Standard proctor test results showed general decrease in MDD values and increase in OMC values which may be obvious as the specific gravity of the additives is less than that of the soil. Also UCC test results indicated a tremendous improvement in the strength of both the soils with the improvement of up to 11.38 and 6.03 times the strength of the virgin soils at 7 days curing period with combination of S1+4%CCR+4%CSA and S2+6%CCR+4%CSA respectively. Hence CCR and CSA can be employed for expansive soil stabilization subject to further researches.*

Keyword: *Stabilization, Expansive Soil, Calcium Carbide Residue (CCR), Coconut Shell Ash (CSA) and Unconfined Compressive Strength.*

1. INTRODUCTION

The increasing population of the world, especially developing nations has led to increasing demand for roadways, railways, housing facilities and other infrastructures. Soil with higher stability is required to bear the weight of these structures; generally speaking, the stability of any construction related structure indirectly or directly depends on the soil stability. Expansive soils swell or increase in volume in monsoon seasons on imbibitions of water, and shrink or reduce in volume because of evaporation of water in dry seasons [1]. As a result of the alternate swelling and shrinkage of expansive soils, structures such as foundations, pavements and residential buildings etc constructed on it experienced severe damage. The objective of expansive soil stabilization may be to stabilize volume change characteristics, modify plasticity and improve workability, or modify plasticity and volume change characteristics while substantially improving strength. Generally, engineers aim to achieve the last one because the subgrade layer must not only be volumetrically stable, but must also support traffic or building loads. The issue then becomes what protocol to use to achieve stabilization and how to validate stabilization in clay soils. Compacting in-situ soil mixed with cement slurry is an extensively used soil improvement technique for expansive soil that is in relatively a dry state. The advantage of this technique is that adequate strength is achieved in a short period of time.

2. LITERATURE REVIEW

For the past several years researchers have recognized the use of locally available materials which are cost effective available from industrial and agricultural wastes to improve the properties of expansive soils with the aim to reduce stabilization costs, related to conventional stabilizing agents such as cement as well as the emission of CO_2 related to cement manufacturing process. Waste materials, such as fly ash, rice husk ash, sawdust ash, sugarcane straw ash, and coconut shell ash etc has been widely applied in practice in addition to cement and lime. [2, 3, 4, 5, 6, 7]. $Ca(OH)_2$ rich material like CCR together with pozzolanic materials such as Fly ash, rice husk ash, biomass ash etc have been widely used to completely replace cement in stabilization of expansive soils. [8, 9, 10, 11, 12, 13, 14, 15] Etc.

Calcium carbide residue (CCR) is a by-product of the acetylene production process that contains mainly calcium hydroxide $Ca(OH)_2$. Compared to hydrated lime, CCR has similar chemical and mineralogical compositions. The $Ca(OH)_2$ contents are approximately 96.5% and 76.7% for hydrated lime and CCR respectively, CaO contents are 90.13% and 70.78% for the hydrated lime and the CCR, respectively. The high $Ca(OH)_2$ and CaO contents of CCR indicates that it can react with pozzolanic material such as CSA and produce a cementitious material. The production of CCR is best described by the following equation:

$$CaS2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2 \qquad (1.1)$$

From equation (1.1) sixty four gram (64g) of calcium carbide (CaS2) provides twenty six grams (26g) of acetylene gas (C_2H_2) and seventy four (74g) of CCR in terms of $Ca(OH)_2$. [15] found that the wet-dry cycled strength of stabilized clay was considered insufficient according to recommendations by [16]. [17] Reported the possibility of using CCR and fly ash to stabilize a nonplasticy, silty sand. The study of soil stabilization with a mixture of CCR and pozzolanic materials is an engineering, economic, and environmental challenge for geotechnical engineersand researchers. [18] Illuminated that the ratio of calcium carbide residue to rice husk ash of 50:50 by weight gives the highest compressive strength. Compressive strength of as high as 15.6 MPa at curing age of 28 days and increased to 19.1 MPa at 180 days. [9] Realized that Fly ash disperses the soil-cement clusters into smaller clusters, thereby increasing the reactive surface for hydration and pozzolanic reactions. [13,19] Discovered that highest strength was obtained at soil water slightly less that of the OMC for unstabilized soft bankok clay while for the stabilized soil in was found to be at 1.2 OMC. [12] Expounded that CCR and FA can be employed for soil stabilization based on soaked and unsoaked strength of the soil and also the strength of the stabilized soil increase with the increase in the curing period. [11] Recommends the use of index properties test for finding the fixation point of CCR there by mixing it with different percentages of a pozzolanic material in order to find the optimum mix. [20] Explored the use of CCR as an alkaline activator in fly ash geopolymer. The maximum 7-day soaked strength of clay-FA geopolymers is found to be 2154 kPa at Na_2SiO_3/water ratio of 0.6 and FA replacement ratio of 15%, which is greater than the specification for the Department of Rural Roads, Thailand (i.e. 1750 kPa) for stabilized subgrade materials. This implies that the clay-FA geopolymer can be applied in road subgrade applications.

India is the second largest coconut producing country in the whole world with 20% of the world production. Hence a lot of waste such as coconut shell and husk are being generated. Using coconut shell ash for soil stabilization purposes will serve as yet another way of reducing this waste. Coconut shell ash is a silica rich waste which when used in conjuction with calcium rich material will yield a cementing property through pozolanic reaction. [21, 22] Explicated that can be employed to improve the geotechnical properties of soil samples within the range of A1-A3. Coconut shell, leaf and husk ash is illustrated to have improved the strength of sandy clayey and clay of medium compressibility [4].

This paper intends to study the influence of CCR and CSA in stabilization of soil. CCR being industrial and agricultural wastes with create nuisance to the environment, utilizing them in this will undoubtedly paved yet another way of turning these materials from waste to something useful and economical.

3. MATERIALS AND METHOD

3.1 Soils (S1 and S2)

Soil samples S1 was collected from Kanabir Village, Potheri which is about 4km away from SRM University while S2 was collected from Salem, specifically Attur respectively. S1 was collected from a construction site. The soil in the site was so bad that special type of foundation (mat foundation) has to be provided so as to sustain multi storey building and to counter attack possible earthquake. S1 and S2 were dug out at a depth of 2m and 1m below the ground surface respectively. Both the samples were then spread under the sun, dried and pulverized using the pulverizer in Soil mechanics laboratory, making it ready for conducting the experiments. Preliminary tests were conducted on the virgin samples for identification and classification in accordance with IS 2720. Base on the tests results shown in table 1, S1 and S2 can be classified as CI and CH based on IS classification of soil.

3.2 Calcium Carbide Residue (CCR)

CCR was obtained from gas welding shop Maraimalainagar Kattankulathur, Tamil Nadu. It was dried and sieved through 225 micron IS sieve.CCR is a waste which normally goes to the waste dump site and create nuisance to the environment.

3.3 Coconut Shell Ash (CSA)

Coconut shell was purchased from C. Mathai & CO, dealers in coconuts,l Bharathi salai, Chennai . The ash was obtained using open air burning of the coconut shell, the ash was then sieved through 225 micron IS sieve.

Table 1: Basic Soil Property

Experiments	S1	S2	Unit
Liquid Limit	46	69	%
Plastic Limit	20.11	23	%
Plasticity Index	25.89	46	%
Shrinkage Limit	10.85	9.77	%
Specific Gravity	2.55	2.6	
Differential Free Swell	65	90	%
MDD	1.67	1.47	g/cc
OMC	18	24	%
UCC	0.8	1.4	g/cm^2
CBR	2.7	3.2	%
Gravel	0	0	%
Sand	25.75	17.7	%
Silt and Clay	74.29	82.2	%
IS Classification	CI	CH	

4. RESULTS AND DISCUSSION

4.1 Atterberg's Limits Tests

Atterberg's Limits Tests were conducted as per the [23].

Liquid Limits (W_L) and Plastic Limits (W_P) tests were conducted on both soils (S1 and S2) after been stabilized with CCR at 0, 2, 4, 6, 8, 10, & 12% respectively. The essence is to determine the fixation point of CCR in both soils (S1 and S2).

Fixation point is the point at which the changes in plasticity index (PI) is insignificant is designated the fixation point of CCR. At this point all the natural pozolanic materials in the soil has been utilized by $Ca(OH)_2$ in CCR. From fig.1 and 2, the percentage of CCR was found to be 4 and 6% for soil S! and S2. The variation in the percentage between the soils may be due to the variation in chemical contents of the soils as they belong to different class (CI and CH soils).

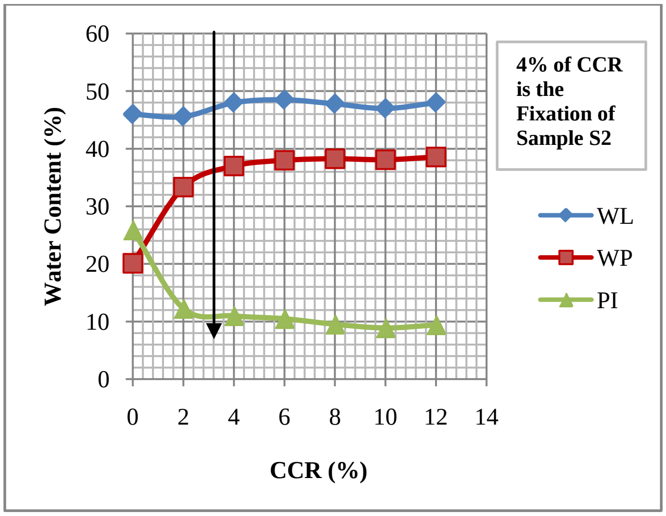

Fig. 1: Index properties of stabilized Soil S1 Stabilized at Different CCR Contents

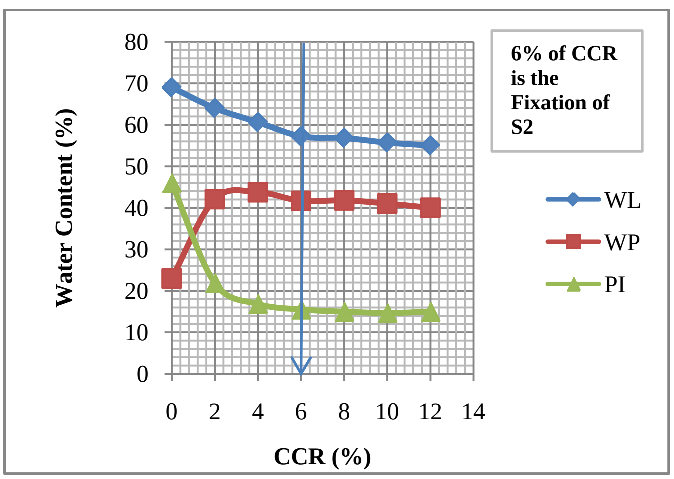

Fig. 2: Index Properties of Soil S2 Stabilized with Different CCR Contents

5. STANDARD PROCTOR TEST

Standard proctor test is essential in determining the MDD and OMC of a soil. At this point the soil is expected to perform at its peak. Standard proctor test was conducted on the virgin soils alone, (S1 + 4%CCR) and (S2 + 6%CCR) mix with 0, 4, 9, 14, and 19%CSA. The test was conducted as per [24] Figure 3 and 4 illuminated the standard proctor curves for both S1 and S2.

5.1 Effect of CCR and CSA on MDDs of the Soils.

It is conspicuous from table 2 that MDD of the virgin soil is greater than that of the stabilized soil, only MDDs at 19%CSA come close to that of the virgin soil, the scenario is the same for both S1 and S2. MDDs at 4%CSA and 9%CSA are almost the same for both S1 and S2. In general, there is a noticeable reduction in MDDs in both S1 and S2 as the additives are added up to 9%CSA after which it tends to increase to a value close to that of the virgin soil. The decrease in the MDD is attributed to the fact that the specific gravity of the soil is greater than that of the CCR and CSA; as such CCR and CSA are lighter in weight than the soil.

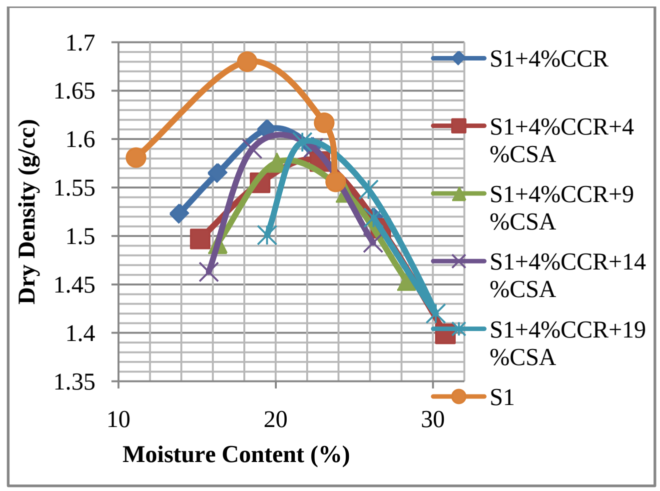

Fig. 3: Standard Proctor curves of Soil S2 Treated with Different CCR and CSA Combinations

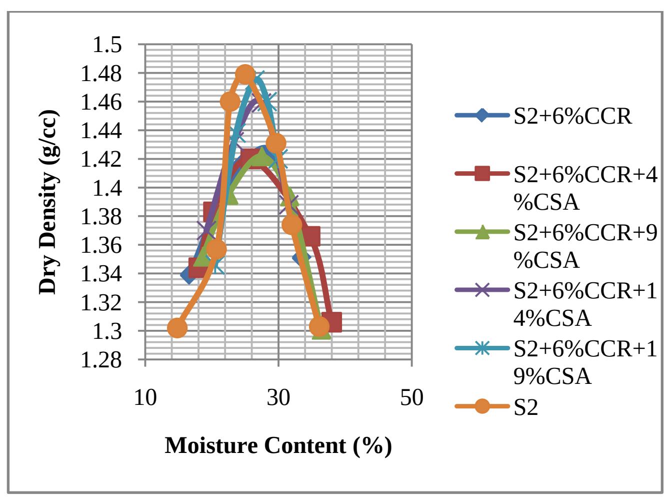

Fig. 4: Standard Proctor Curves of soil S2 treated with Different CCR and CSA Combinations

5.2 Effect of CCR and CSA on OMCs of the soils

Generally, the OMC tend to increase with theincrease in the percentage stabilizers. this may be attributed to the fact that CSA absorbs more moisture when added to the clay which may be required for the pozolanic reaction. OMC at 9%CSA and 14%CSA are almost the same for S1 while OMC at 14 and 19%CSA are the same for S2. The relationship is best represented in table 2 and 3.

Table 2 MDDs and OMCs for Soil S1

Combination	MDD (MN/m^3)	OMC (%)
S1	16.70	18
S1+4%CCR	16.13	20
S1+4%CCR+4%CSA	15.78	22
S1+4%CCR+9%CSA	15.78	20.4
S1+4%CCR14%CSA	16.05	20.2
S1+4%CCR+19%CSA	16.00	22

Table 3 MDDs and OMCs for Soil S2

Combination	MDD (MN/m^3)	OMC (%)
S2	14.70	24
S2+4%CCR	14.28	27.8
S2+4%CCR+4%CSA	14.20	25.5
S2+4%CCR+9%CSA	14.22	27.5
S2+4%CCR14%CSA	14.61	26.8
S2+4%CCR+19%CSA	14.76	26.8

6. COMPRESSIVE STRENGTH TEST (UCC)

UCC test was conducted using a cylindrical mould popularly known by the name split mould. Specimens of dimension 38mm diameter and 76 mm height were prepared at their various OMCs and MDDs, casted, compacted in the split mould and then extruded. For virgin soils and treated soils with CCR and CSA for zero days curing, the test was conducted immediately after the sample is been produced. For soil treated with CCR and CSA, curing is done by placing the specimens in air tight polythene bag for 3 and 7 days after which they were tested at the end of curing period until failure occurred. All the specimens prepared, casted and tested as per [25].

Table 4: UCC Test Results for Treated and Untreated Soil S1.

Soil Mixture	UCC (kg/cm^2) S1 Curing period 0	3	7
S1	0.8		
S1+4%CCR	5.53	8.72	8.73
S1+4%CCR+4%CSA	4.07	4.36	9.02
S1+4%CCR+9%CSA	2.50	2.97	5.41
S1+4%CCR+14%CSA	2.40	2.50	3.20
S1+4%CCR+19%CSA	1.47	1.45	2.00

Table 5: UCC Test Results for Treated and Untreated Soil S2

Soil Mixture	UCC (kg/cm^2) S2 Curing period 0	3	7
S2	1.4		
S2+6%CCR	5.53	6.69	8.14
S2+6%CCR+4%CSA	5.52	6.78	8.44
S2+6%CCR+9%CSA	4.65	4.42	5.24
S2+6%CCR+14%CSA	2.20	2.12	2.33
S2+6%CCR+19%CSA	1.42	1.45	2.04

Results of UCC tests indicated a tremendous increase in the strength of both the soils as they were treated with both CCR and CSA in general (Table 4 and 5). Even though CCR alone is proved to be Unsuitable for soil stabilization, it is employed in this research in order to see if there will be increase in the strength as CSA is added. When CCR was added alone the strength multiplies by 6.84, 10.9 and 10.9 compared to that of virgin S1 at curing period of 0, 3, and 7 days respectively. In the case of S2 the strength multiplies by 3.95, 4.77 and 5.81 at curing period of 0, 3, and 7 days compared to the strength of the virgin S2. When CSA substituted (S1+4%CCR) and (S2+6%CCR) in varying percentage of 4, 9, 14, and 19%, trends of decrease in strength is observed with highest strength at 4% CSA in both the soils. All the outcomes of the strength at the substitution levels were greater than that the strength of the virgin soils. Minimum increase in strength was when 19% CSA was added to both soils but still the strength multiplies the that of the virgin soils by 1.8, 1.8, & 2.5, and 1.25, 1.43 and 1.46 at curing period of 0, 3, 7 days for S1 and S2 respectively. Appreciable strength was also conspicuous at 9 and 14%CSA. Increment in strength of up to 6.76 and 3.16 times the strength of the virgin soil was observed at 7 days curing period for S1 and S2 respectively when 9%CSA was used. Also the strength multiplies by 3.83 and 2.65 at 14%CSA for S1 and S2 at 7 days curing period. It is obvious from the results that combination of S1+4%CCR+4%CSA and S2+6%CCR+4%CSA happened to give maximum strength at seven days.

This is due to the fact that the excess CaO which is not been utilized by the natural silica in the soil is being fully utilized by the silica in the CSA. Strength obtained from S1+4%CCR+4%CSA is 5.09, 5.45, and 11.38 times that of the virgin soil when cured for 0, 3, and 7 days respectively while that of S2+6%CCR+4%CSA is 3.94, 4.8 and 6.03 times that of the virgin soil when cured for 0, 3 and 7 days respectively. Stress strain curves for both treated and untreated S1 and S2 are depicted in figure 5 and 6. Development in strength is best represented graphically in figure 7 and 8.

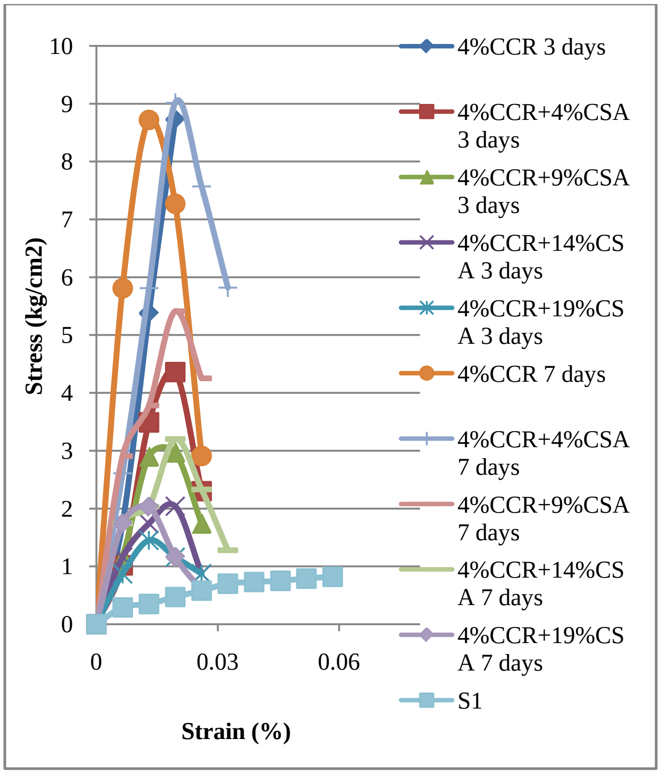

Fig. 5: Stress Strain Curves for S1 Treated with Different CCR and CSA Contents

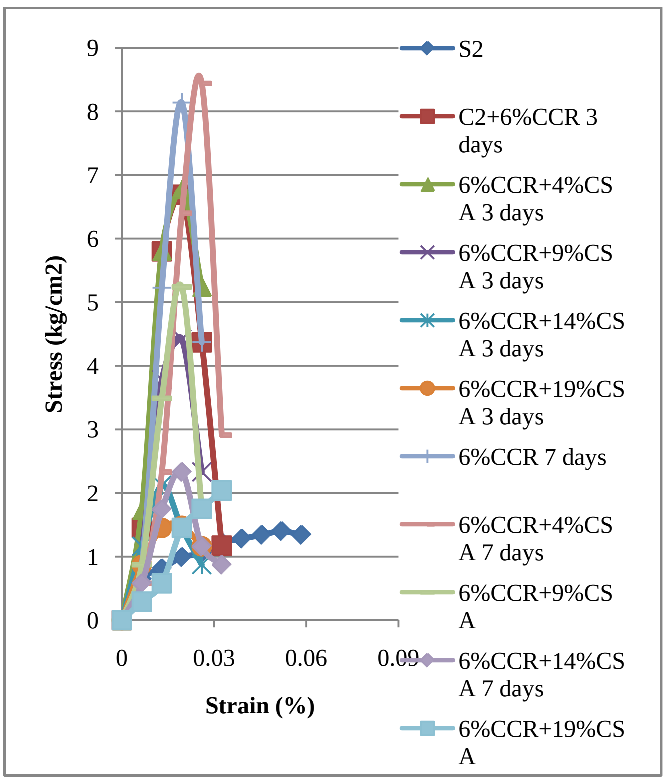

Fig. 6: Stress Strain Curves for S2 Treated with Different CCR and CSA Contents

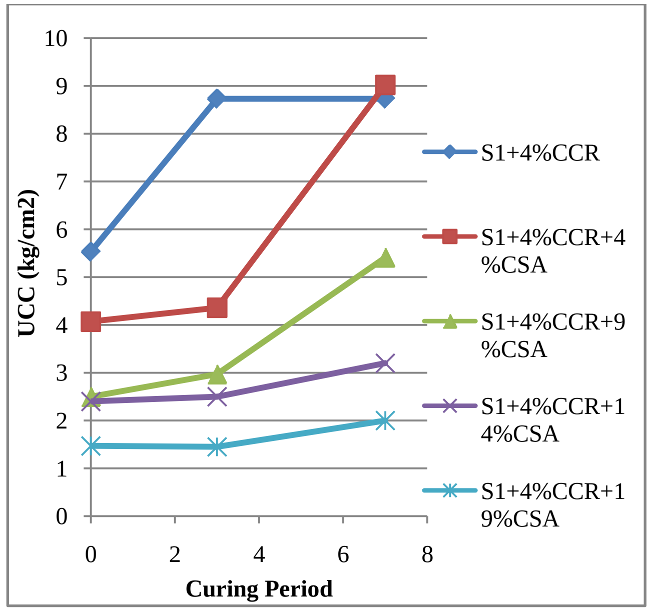

Fig. 7: Strength Developments in Treated S1 with Curing Period

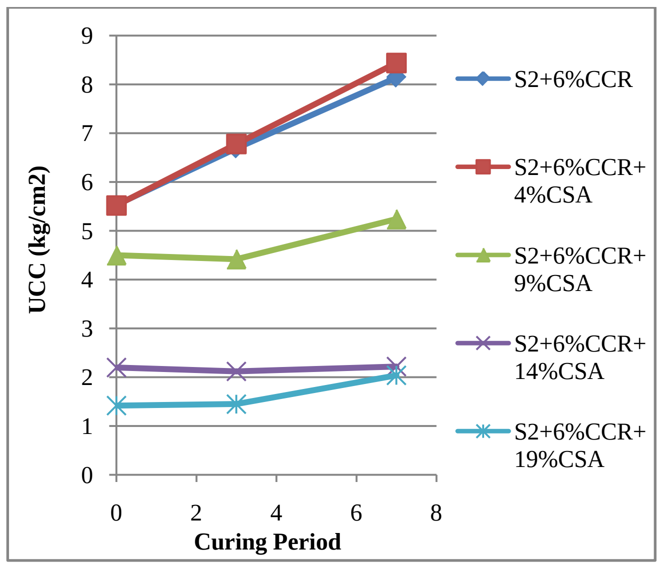

Fig. 8 Strength Developments in Treated S2 with Curing Period

7. CONCLUSION

CCR and CSA were employed to stabilize two different classes of expansive soils (CI and CH) and experiments were conducted in the laboratory within the limit of experimental errors.

Fixation point of CCR was found to be 4% and 6% for CI and CH soil (ie S1 and S2) respectively.

Also MMDs found to decrease with respect to that of the virgin soils as tboth soils were treated with CCR and CSA while OMC increases.

Minimum improvement in strength occurred at S1+4%CCR+19%CSA and S2+6%CCR+19%CSA with the improvement os 2.5 and 1.46 times that of the Virgin Soil for in soil S1 and S2 respectively .

From the results of the experiments it can be suggested that CCR and CSA can be recommended for use in expansive soil stabilization subject to further research.

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