Role of Wood Ash and Calcium Chloride in Amending the Early Strength Development of an Expensive Soil

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Abstract - Building on weak or soft soils presents issues such as differential settlements, insufficient strength, and significant compressibility. Clayey soils are weak, and as a result, a pavement will not be able to withstand it for long enough to work as intended. There are several methods available to boost the soil's ability to support more weight, such as providing reinforcement and stabilizing the soil. One way to improve the geotechnical qualities of soil is soil stabilization, which has become an important practice in construction engineering and allows for the successful use of industrial wastes as a stabilizer. This method's appeal is increasing due to its adaptability and accessibility. The stabilization of waste materials makes it possible to construct roads at a reasonable cost. The investigation that was done to determine whether adding wood ash and calcium chloride enhanced the properties of clayey soil is described in the current article. Unmodified soil is combined in a variety of percentages with wood ash and calcium chloride to produce the optimal admixture% required for soil stabilization. Laboratory tests such as Atterberg's limit, Compaction test, CBR test, and UCS test were performed for both modified and unmodified clayey soil as part of this comparative study. In this study Wood Ash and Calcium Chloride were used to stabilize Expansive soil. Using index properties tests Wood Ash was fixed at 12% respectively. Calcium Chloride was then varied (i.e. 02%, 04%, 06% and 08%).

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

INTRODUCTION

Fine-grained soil with less than 2 micron particles and poor geotechnical qualities is referred to as clayey soil. High clay soils have a propensity to expand and contract in response to changes in moisture content, which can cause pavements and buildings to settle. Clayey soil, which makes up the majority of the country's land, typically has poor geotechnical qualities, such as low shear strength, poor drainage, excessive shrinkage, etc. The primary components of soil that keep a structure stable are its strength parameters. Fine-grained clayey soils are under the expansive kind of soils because they contain highly water-absorbing minerals like montmorillonite and other similar ones. The amount of soil increases when it absorbs water. The more water they take in, the larger the volume becomes, and the soil begins to contract as the water content falls. This chopping and fluctuating swelling and shrinking results in a significant shift in the soil's volume, which has disastrous effects on the structures erected upon it. The common sorts of damage caused by soil swelling include floors, cracked foundations, basement walls, and many more.

2. Literature Review

Samaila Saleh et al. (2024) This study looks at the potential of waste calcium carbide (WCC) and wood ash

(WA) as soil stabilisers to improve the engineering characteristics of subgrade soil. The investigation begins by characterising the properties of the untreated soil, indicating a liquid limit of 24.6%, linear shrinkage of 7.6%, and a non-plastic nature due to the lack of a plastic limit. The findings indicate that the incorporation of WCC and WA leads to a reduction in the liquid limit by a maximum of 18.70% and linear shrinkage by a maximum of 55.26%. Importantly, CBR values significantly improved, with the soil treated with 6% WCC and WA demonstrating a CBR value of 26.9%, exceeding the subgrade acceptability requirement in road construction. This study highlights the potential of WCC and WA as cost-effective and sustainable soil stabilisers, particularly in areas where traditional stabilising materials are limited.

Iqbal Javeed Lone et al. (2022) This study focuses on improving the physical properties of black cotton soil by stabilising its atterberg limits, standard proctor, unconfined compressive strength and California bearing ratios in accordance with Indian standards. Variation of lime, wood ash was separately and combined in study was investigated, with replacement rates of 2 %, 4 %,6 %, up to 8 %, and 8 %, 16 %, up to 24 %, respectively. When lime was added, it was found that OMC increased while MDD reduced. When the two were combined, OMC marginally increased while MDD also somewhat decreased. In both instances, the increment in CBR value tends to rise up to the optimum value and then begin to fall after it. The greatest increase in the lime case was 266.92 %. Additionally, when both additions were employed in various combinations, the ideal ratio of 6% lime and 16 % wood ash was discovered, increasing the CBR value by 594%.

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%).

Berjees Anisa Ikra et al. (2018) Stabilization of soil can be done by different methods such as mixing the soil with cement, wood ash, brick dust, rice husk etc. In this study wood ash was used with soil for stabilization purpose. For laboratory experiment, standard proctor test was used. In the laboratory experiment, 8%, 10%, 12%, 14%, 16%, 18% water was added in the soil. From the observed data it was found that, within a certain limit the increase of water content increased the value of dry density, after attaining a peak point the dry density decreased with the further increase of water content. From the peak value of the graph, maximum dry density and optimum moisture content can be determined. The same experiment was continued for different percentage (2%, 4%, 6%, 8%, 10%, and 12%) of wood ash mixing with soil. From the experimental value it was observed that maximum dry density of the sample was decreased with the increasing percentage of wood ash with sample.

Bayshakhi Deb Nath et al. (2018) Geotechnical Properties of Wood Ash based composite Fine-Grained Soil. Ash stabilization causes an increase in unconfined compressive strength in the soft clayey soil, and 10% wood ash-clay mixture optimizes the results. There is a sharp improvement in the shear strength parameters with the addition of wood ash. The larger is the percentage of wood ash mixed , the more the greater would be.

Bade et al. (2017) investigated the index properties of black cotton soil using wood shaving ash concluded that plasticity index decreases as the percentage of wood ash increases and is added in the ratio 15%,20% and 25% by weight of soil. Plasticity index decreases from 25% to 16.56% with 25% addition of wood ash by weight of soil.

Butt et al. (2016) used saw dust ash to improve soil characteristics performed California bearings ratio(CBR), compactions and unconfined compressive strengths test concluded that maximums dry density decreases from 1.81g/cc to 1.365g/cc with the increase in S.D.A from 0% to 12% and optimum moistures content increases from 11 to 25.7% as they percentage of ash increases up certain limit, CBR value increases and UCS was increased from 248kN/m3 to 313.14kN/m3 with addition of 4% S.D.A which is taken optimum and states that strength is increased due to pozzolanic reactions of S.D.A to form cementious product b/w CaoH present in the soil and pozzolona present in S.D.A.

Uchariya et al. (2016) studied the stabilization of clay by using wood ash and fly ash. They stated that ash from biomass fuel contains a significant amount of CaO and addition of such material will increase the physical as well as chemical properties of soil. Properties to be increased are CBR value, shear strength. The plasticity was reduced by 32% and CBR value is increased from 25% to 50% . After experiments it is obtained that highest strength increase are developed after 7 to 14 days of curing at 20% to 30% of wood ash and fly ash clay mixture. At last they concluded that wood ash material can stabilize the clay soil.

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 in greater strength.

Hilbrich et al. (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).

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.

Roshni et al. (2014) done study on strength behavior of expansive soil with PG and wood ash. Additives were mixed with soil as 4% P.G and 10%, 12%, 14%wood ash. After experiments were done, results were that UCS value and CBR value increases after 14 days curing. CBR has increased from 3.14 % and 2.11% to 34.31% and 56.82% for both wood ash and PG.

Sayalak et al. (2015) indicated that solid calcium chloride has high water absorbing performance. At a relative humidity of 95%, solid $CaCl_2$ 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 presence of water which will lead to ion exchange reactions with Na^+ and K^+ ions initially absorbed on the clay particle surface. Consequently, the soil plasticity will decrease and strength will increase.

T.Deepika et al. (2017) done study on strength behavior of black cotton soil using wood ash as stabilizer. In this test maximum strength is obtained when soil samples are treated with 8% wood ash. W.A is added in ratios 2, 4, 6, 8 & 10%. CBR is max. At 8% wood ash. UCS value is 452.13KN/m2 under 8% W.A after 28 day curing. 8% wood ash by weight of soil is taken optimum.

Hausmann et al. (2014) have stated that CaCl2 enjoyed its wide use as dust palliative and frost control of subgrade soil. Calcium chloride has hygroscopic property. This means that it attracts and absorbs water which is a function of relative humidity and temperature. It can easily liquefy in moisture in its own absorption.

Zumrami et al. (2016) study of laboratory investigation of expansive soil stabilized with Cacl2. There is a decrease in plasticity and swelling of stabilized expansive soil with percentage increase of cacl2. Plasticity and free swell are reduced to 60% and 70% with 15% addition of cacl2. The shear strength increases upto 5% Cacl2, above this %age, there is percentage decrease which may be due to absorption of extra moisture.

3. Materials

3.1 SOIL

Source of soil

The clayey soil used in this investigation were collected from Samba district of J&K from where basantar river flows (India). 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 4.75 mm size sieve and stored in such way that, there is very minor chances of absorption of moisture 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).

Table no. 1 Properties of soil used in the study

S.No.	Properties	Result
1.	Liquid limit (%)	43
2.	Plastic limit (%)	22
3.	Plasticity Index (%)	21

4.	Specific Gravity	2.59
5.	Free Swell Index	18%
5.	Maximum Dry Density (gm/cc)	1.762
6.	Optimum Moisture Content (%)	15.89
7.	Soil Classification	CI (Intermediate Compressive Clay)
8.	CBR (%)	2.9
9.	UCS (kN/m$^{2)}$	82.06

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^{0}C
5	Boiling point	1600^{0}C
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 WOOD ASH

Source of WOOD ASH

Wood ash is obtained by burning wood wastes and wood flour taken from local saw mill and brought to laboratory in bags oven dried for 248 hours and is sieved through 4.758 mm sieve, and kept in polythene bags and is used for research work. The geotechnical properties are presented in table 4 respectively.

Table 4:- Chemical Composition of WOOD ASH

Sr. No.	Constituent	Value (%)
1.	Silica (SiO_2)	28.50
2.	Alumina (Al_2O_3)	14.77
3.	Iron Oxide (Fe_2O_3)	3.44
4.	Calcium Oxide (CaO)	29.80
5.	Magnesium Oxide (MgO)	9.32
6.	Sodium oxide(Na_2 o)	3.59
7	Potassium oxide(k_2 o)	10.38
8	Specific gravity	1.65-1.70

4. EXPERIMENTAL RESULTS

4.1 STANDARD PROCTOR TEST

Table no. 5: Results of OMC and MDD for mix proportions of Clayey Soil with Wood ash and Calcium chloride

CS:W.A: $CaCl_2$	M.D.D (g/cc)	O.M.C %
84:12:04	1.58	15.91
82:12:06	1.55	16.20
80:12:08	1.53	16.50

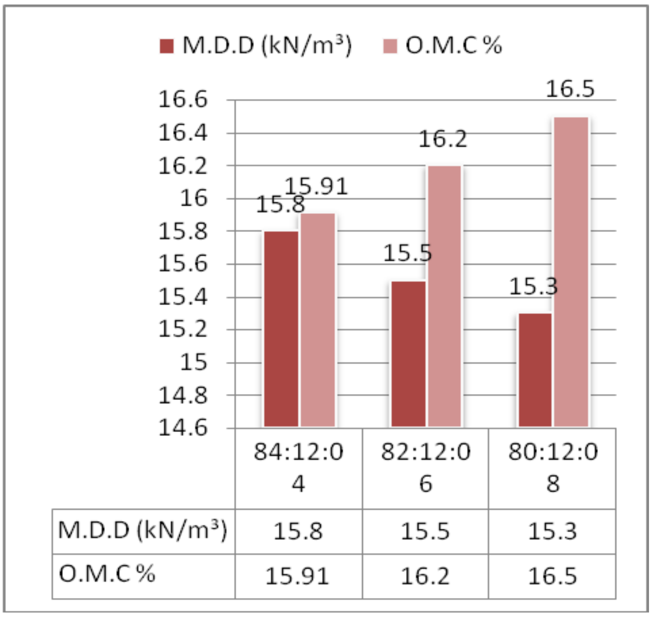

Fig:-1 Combine graph b/w MDD and OMC of Clayey Soil with Wood ash and Calcium chloride of different proportions

Table 6: Results of UCS of Clayey Soil with Wood ash and Calcium chloride

CS : W.A : $CaCl_2$	Curing (Days)	UCS (kPa)
100 : 00 : 00	7	82.6
84 : 12 : 04	7	205.81
82 : 12 : 06	7	241.25
80 : 12 : 08	7	233.05

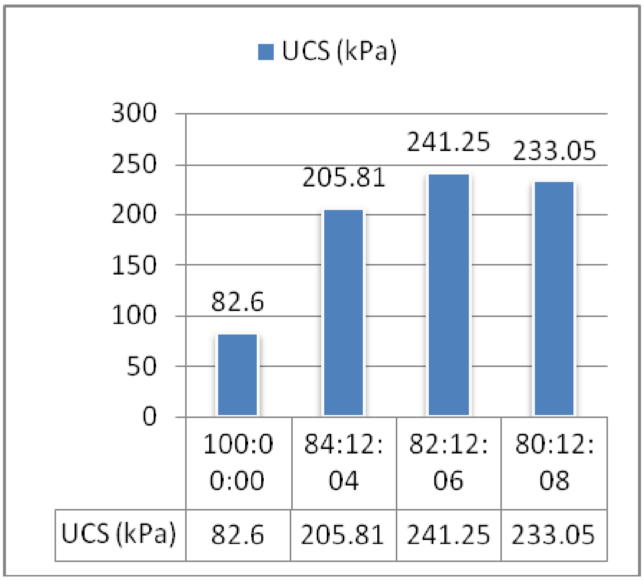

Fig:-2 Combine graph b/w UCS Values of Clayey Soil with Wood ash and Calcium chloride of different proportions

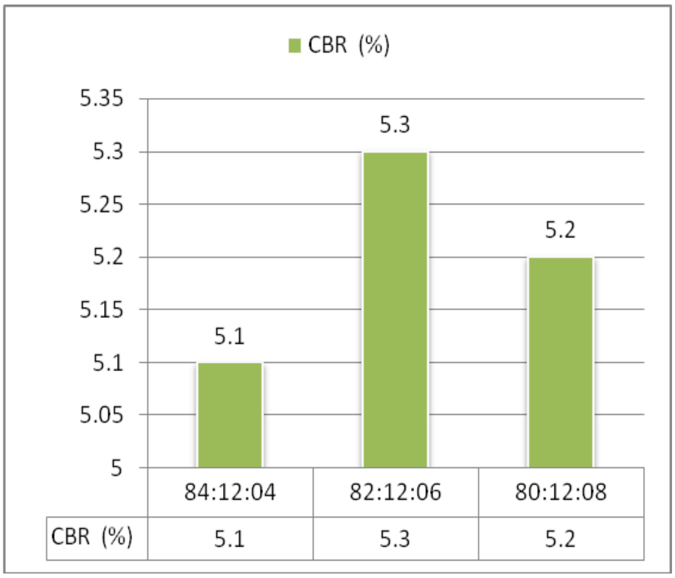

Fig:-3 Combine graph b/w CBR Values of Clayey Soil with Wood ash and Calcium chloride of different proportions

Table 7: Results of CBR of Clayey Soil with Wood ash and Calcium chloride

Mix Proportions (CS:W.A: $CaCl_2$)	**CBR (%)**
84:12:04	5.1
82:12:06	5.3
80:12:08	5.2

5. DISCUSSIONS

STANDARD PROCTOR TEST:

- An increase of OMC from 15.89 to 18.10% and decrease of M.D.D. from 1.762 to 1.63 g/cc when the percentages of Wood ash are used as 8%, 12% and 16% respectively. In this value of MDD is decreased upto 12% wood ash, after that it increases. Therefore, value of 12% is taken optimum
- There is an also increase of OMC from 15.89 to 17.5% and decrease of MDD from 1.762 to 1.63 g/cc when the percentages of Cacl2 are used as 3%, 5%and 7% respectively.
- There is an also increase of OMC from 15.89 to 16.5% and decrease of MDD from 1.60 to 1.53 g/cc when the percentages of CaCl2 vary from 4, 6 and 8% and Wood ash is fixed at 12%.

- Specific gravity of Wood ash is lower than as compared to soil. So MDD is decreased and OMC is increased.
- With Wood ash kept constant at 12% MDD decreases with an addition of Calcium chloride content in soil mix. The reason behind of such behavior is Calcium chloride is lighter in weight and it has high water absorption properties because of presence of calcium oxide and hence OMC increases with increase of calcium chloride content.

CBR TEST:

- UCS value of virgin soil enhances fundamentally with expansion of Wood ash contents. The UCS value increment from 82.6kN/m² to 152.08kN/m² with expansion of Wood ash up to 12 % in the wake of curing time of 7 days. U.C.S. value decreases with more expansion of wood ash. Therefore the mix with 12% wood ash content is taken as optimum.
- The UCS value of virgin soil is 82.6kN/m² and it increases to 1.84 times with addition of 12% Wood ash. This improvement is because of increases the cementation property of soil.
- The UCS values of virgin soil also improve considerably by keeping wood ash value fixed at 12% and calcium chloride in %ages 4, 6 and 8. The value increases from 82.6 kN/m² to 241.25kN/m² with the addition of wood ash and calcium chloride upto 6% and then further addition of calcium chloride content decreases UCS value. Therefore wood ash 12% and calcium chloride 6% is taken as optimum.
- The reason behind of this when wood ash and calcium chloride comes in contact with water, pozzolanic reactions takes place during the curing period. With further increase in the amount of calcium chloride, U.C.S. value starts decreasing because of lumps are formed with extra addition of calcium chloride in 6 % calcium chloride with 12% wood ash.

UCS TEST:

- An increase of CBR value was observed when the wood ash is added to soil. This increases at the 12% of wood ash after that CBR value decreased. The optimum value of wood ash was found at 12% in that case, CBR value increase 1.50 times to the CBR value of virgin soil when observed in soaked conditions.
- Presence of pozzolanic compounds in wood Ash and CaOH available in soil might increase the CBR value due to formation of cementitious compounds in soil.
- When calcium chloride is added to virgin soil the CBR value of virgin soil is 2.9 and it increases to 1.34 times with addition of 5% calcium chloride when observed in soaked conditions. This enhancement is because of binding action of calcium chloride.
- The CBR value of virgin soil is 2.9 and it increase to 1.71 times when wood ash 12% and calcium chloride 6% is added to virgin soil. This enhancement in CBR may be because of the gradual formation of hydration compounds in the soil due to the reaction between the stabilizers and the essentials particle present in the soil. The increase in CBR value from 4.9 to 5.3 when wood ash is fixed at 12% and calcium chloride added at different ratios i.e. 4, 6 after that it decreases. As a

result of calcium chloride is a light material and with increment the amount of lumps are formed.

6. CONCLUSIONS

- Three samples containing three different contents of calcium chloride (3%, 5% and 7%) with wood ash (8%, 12% and 16%) were tested at 7 cure days to verify the effectiveness and optimum ratio of calcium chloride and wood 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:-
- 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 wood ash on the clayey soil sample. The results showed that Calcium chloride and wood ash could improve the UCS value, Dry density and CBR Percentage of clayey soil sample.
- The different percentages of $CaCl_2$ and wood ash used in this study were 03%, 05% & 07% and 8%, 12% and 16%. Finally, the value of wood ash was fixed to 12% with variation of $CaCl_2$ (4%, 6% and 8%) to clayey soil.
- Addition of $CaCl_2$ and wood ash with clayey soil decreases maximum dry density and increases the optimum moisture content of the soil sample.
- The addition of the fixed quantity of wood ash 12% with changing the content of $CaCl_2$ increases the value of optimum moisture content and decreases the value of maximum dry density.
- The optimum value of wood ash used in this research was 12% because the maximum value of UCS was found at 12% wood ash.
- The UCS value increases with an increase of $CaCl_2$ content along with a fixed quantity of wood ash. The maximum value of UCS was found at 06% $CaCl_2$ and 12% wood ash. Further increase of $CaCl_2$ content in soil would decrease the UCS value.
- Based on the CBR test results, the value of CBR increases from 2.9 to 5.3.
- The optimum value of California Bearing Ratio was found at 06% $CaCl_2$ and 12% wood ash.
- No more than 4% calcium chloride is recommended to obtain high early strength but if long-term strength is also required, then 6% calcium chloride with 12 % wood ash should be considered.
- Hence, the addition of $CaCl_2$ and wood 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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