ISSN 2229-5518

SOIL STABILIZATION IN SKARDU REGION OF GILGIT BALTISTAN USING WOOD ASH

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Abstract

This research is intended to examine the effect of locally produced wood ash on the engineering properties of soil found in Skardu region of Gilgit Baltistan area of Pakistan and to evaluate their potential use for the stabilization and improvement of engineering properties of soils. Two types of soil were selected from Skardu region, CL-ML and CL. Both types of soil were mixed with 0%, 5%, 10%, 15% and 20% wood ash. XRD test result shows presence of clay minerals in both types of soil, both types of soil are reactive with wood ash. In unconfined compressive strength test optimum percentage of wood ash required for stabilizing the soil is in range of 5% to 10% by weight of soil for both type of soils. CBR test results shows at 10% wood ash mixed with both types of soil give higher CBR value. The use of wood ash may serve as an effective and efficient to stabilize the soil and minimize disposal problem caused by the waste materials.

Key Words: *Maximum dry density, Optimum moisture content, Unconfined compressive strength, California bearing ratio, Skardu region, Wood ash.*

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1 INTRODUCTION

Skardu region is situated on the bank of Sindh River and many other seasonal rivers and streams pass through this area due to which the soil of this region is uneven, it consists of clay, silty clay, silt, sand and gravel. Those areas nearby river bank are mostly clays and those near the mountains are mostly sand and gravel. Due to presence of clay, high water table (due to river) and the extreme climate conditions soil of this area is found to be problematic, results in development of cracks in buildings, damage of roads and other infrastructure. The climate of the Gilgit-Baltistan is very cold in winter while pleasant in summer. Temperature varies between a maximum of 27ºC and a minimum of 8ºC during summer and drop to below 10ºC in winter. In winter season most of the precipitation received in this area is in the form of snow. The average annual rainfall is about 208mm. With the rapid growing population energy crises is also increasing day by day in the region, due to lack of gas and shortage of electric energy the only main source of energy for heating and cooking is wood, as wood is cheap and available in the market. In the month of October to March the residents of this region use "Bukhari" (a wooden combustion chimney) for heating purpose in their homes, shops and offices. Along with the advantage of wood as a source of heating energy, there is one important drawback which is the remaining by-product as wood ash. During wood combustion process the majority of organic material is oxidized and release into air remaining the wood ash which includes all the essential elements like Ca (Calcium), K (Potassium) and Mg (Magnesium) [8] [15]. As wood ash is highly alkalinity due to which it has highly alkali carbonated which act as pozzolanic agent. Wood ash is disposed off without its proper utilization in Gilgit Baltistan. Mostly wood ash is dump in tranches or in dig holes for landfill purpose. It is beneficial to use the stabilization agents which are low-cost and effective to soil stabilization, particularly the wood ash, as it has also added advantage of solving the environmental problem.

Wide use of wood as a fuel and energy sources has led to a considerable increase in the amount of combustion residue. There is an increasing amount of wood ash generation in the world because wood is a renewable resource for energy and an environmentally friendly material therefore, there is an increased interest in using wood for energy production. Currently, most of the wood ash generated in the USA is either landfilled (about 70 percent) or applied on land as a soil supplement (about 25 percent) [14]. Wood ash consists of two different types of materials, i.e., fly ash and bottom ash. The chemical and physical properties depend upon several factors including source and type of wood design and operating parameters of the combustor equipment (especially combustion temperature) and the method of collection of ash. Currently, ASTM specifications do not exist for wood ash for determining their suitability for use as construction materials. Therefore, ASTM C 618, developed for volcanic ash and coal fly ash used [13].

ISSN 2229-5518

1 MATERIAL AND METHODOLOGY

Bulk sample of soil are obtained from a dug pit from different parts of Skardu region and take the sample to laboratory where the samples were dried in an oven before testing.

Wood ash was obtained from households. Test samples were prepared for soil mixtures with 0%, 5%, 10%, 15% and 20% of wood ash, two identical samples of soil were prepared. Modified Proctor test, UCS, CBR, and swell potential of soil were performed. Soaked and unsoaked samples were tested for CBR and UCS test to check the effect of moisture and curing effect on the properties of soil. The treated soils were soaked and cured for 2, 7, 14, and 28 days.

2 RESULTS

2.1 Sieve and Hydrometer analysis

To find the gradation of soil, ASTM D 2487 was followed. Total 400 gm sample was weighted. It was pulverized first and then tested. The test was performed to check the percentage of soil passing through the sieve #200. For CL-ML, 71 % of soil was passed through sieve #200 and for CL, 90 % sample was passed through sieve #200.

Hydrometer analysis test was performed as per ASTM D 422-63. The hydrometer test results showed that in the case of CL-ML, 17 % was clay while for CL, 22 % was clay.

2.2 X-Ray diffraction Test

X-ray Diffraction test result is presented in Fig. 1 and fig. 2. This test shows that quantity of Quartz is more in both samples. This soil also includes Muscovite, Illite and Kaolinite minerals. This test only gives indication of different constituents of soil. Presence of clay minerals in soil react with admixture.

2.1 Modified Proctor Test

Modified Proctor test was performed to draw a relation between OMC and MDD according to ASTM D1557-12. Different percentages of wood ash was used to check maximum effect on the compaction properties of CL-ML and CL. By the addition of wood ash, OMC increases while MDD decreases. For CL-ML with the addition of different percentage of wood ash MDD decreases and OMC increases as shown in Chart. 1.

CL when treated with different content of wood ash, a maximum change was observed at 10%. MDD and OMC values were 1.71 g/cm3 and 20.5 % respectively as shown in Chart. 2.

Flocculation makes compaction difficult, which contribute to the reduction of MDD. Increase in the values of OMC can be explained on the basis of particle size of wood ash. Particle size of wood ash is smaller than that of soil, smaller the size of the particles greater will be its surface area and more water will be required to lubricate the soil particles. The increase in the OMC is also due to the pozzolanic reaction between lime content in wood ash and soil, which requires more water for the completion of the reaction [7] [11] [12].

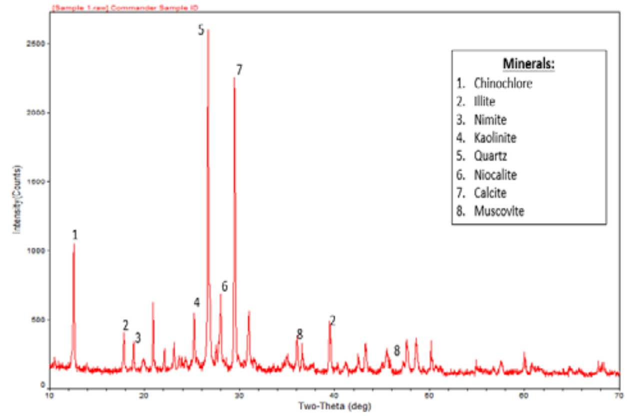

Fig- 1: X-ray diffraction test results of CL-ML

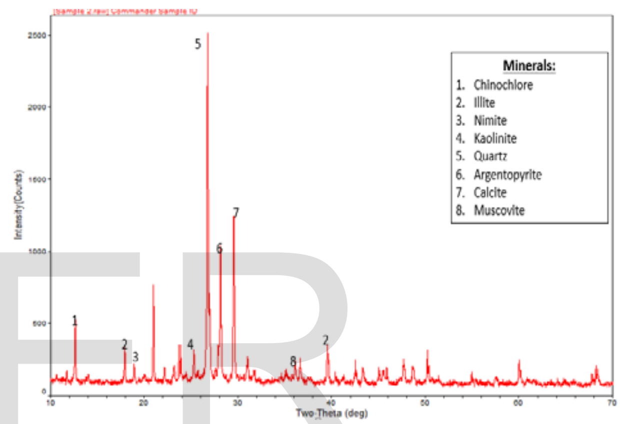

Fig- 2: X-ray diffraction test results of CL

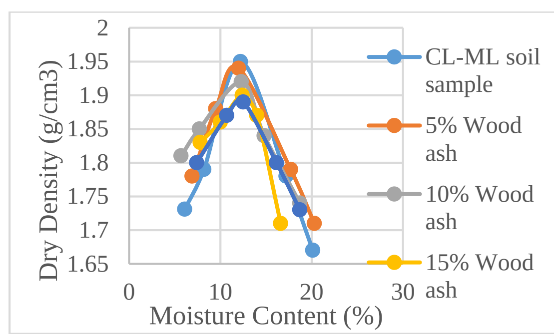

Chart- 1: Compaction Characteristics of CL-ML treated with Wood ash

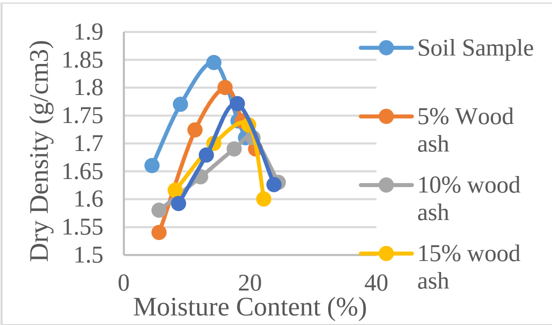

Chart- 2: Compaction Characteristics of CL treated with Wood ash

2.2 Unconfined Compressive Strength (UCS)

UCS tests were performed according to ASTM D2166-13. Two samples were prepared for each trial at OMC and MDD and average of these values were recorded. The percentage of additive giving highest value of UCS was considered as optimum percentage.

Chart no. 3 demonstrate effect of wood ash and the time effect on UCS (un-soaked curing) results for 5%, 10%, 15% and 20% wood ash and CL- ML soil mixture. UCS un-soaked, untreated soil have UCS value of 240.8 kPa and it remains unchanged with curing period. With the addition of 5% wood ash UCS value increases to 352.0 kPa after two days 423.6 kPa after 7 days and 447.8 kPa after 28 days of curing. With addition of 10% wood ash UCS value increases to 349.2 kPa after two days, 420.3 kPa after 7 days and 430.8 kPa after 28 days of curing. With addition of 15% wood ash UCS value increases to 333.8 kPa after two days, 377.1 kPa after 7 days and 388.8 kPa after 28 days of curing. For addition of 20% wood ash UCS value increases to 300.2 kPa after two days, 375.7 kPa after 7 days and 383.7 kPa after 28 days of curing.

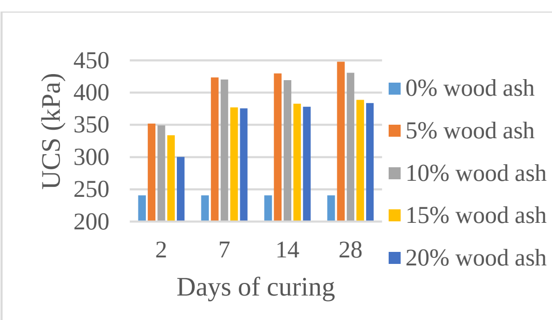

Chart- 3: UCS (un-soaked) results for CL-ML

Chart no. 4 demonstrate effect of wood ash and the time effect on UCS (soaked curing) results against 5%, 10%, 15% and 20% wood ash and CL-ML soil. UCS soaked test results, untreated soil have UCS value of 80.2 kPa, with the addition of 5% wood ash UCS value increases to 175.4 kPa after two days, 184.6 kPa after 7 days and 189.4 kPa after 28 days of curing. For addition of 10% wood ash UCS value increases to 118.4 kPa after two days, 138.5 kPa after 7 days and 154.2 kPa after 28 days of curing. For addition of 15 % wood ash UCS value increases to 109.4 kPa after two days, 110.2 kPa after 7 days and 114.4 kPa after 28 days of curing. For addition of 20% wood ash UCS value increases to 108.6 kPa after two days, 109.4 kPa after 7 days and 112.4 kPa after 28 days of curing.

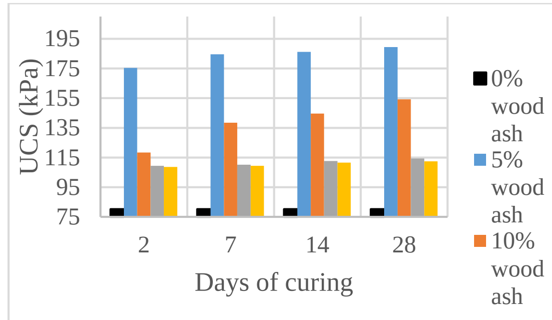

Chart- 4: UCS (soaked) results for CL-ML

Chart no. 5 demonstrate effect of wood ash and the time on UCS (un-soaked curing) for 5%, 10%, 15% and 20% wood ash and CL soil mixture.

Un-soaked untreated soil have UCS value of 255.4 kPa. With the addition of 5% wood ash, UCS value increases to 581.0 kPa after two days, 785.6 kPa after 7 days and 795.6 kPa after 28 days of curing.

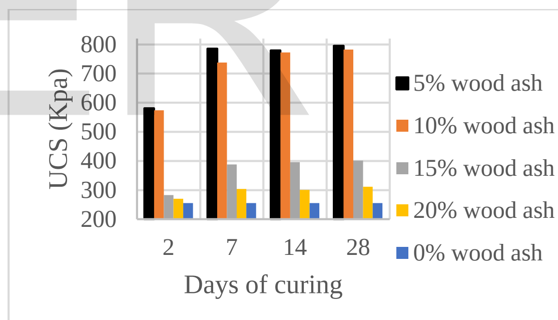

Chart- 5: UCS (un-soaked) results for CL

For addition of 10% wood ash UCS value increases to 574.2 kPa after two days, 737.8 kPa after 7 days and 782.6 kPa after 28 days of curing. For addition of 15% wood ash UCS value increases to 282.8 kPa after two days, 388.3 kPa after 7 days and 401.2 kPa after 28 days of curing. For addition of 20% wood ash UCS value increases to 270.4 kPa after two days, 303.8 kPa after 7 days and 311.7 kPa after 28 days of curing.

Chart no. 6 demonstrate effect of wood ash and the time on UCS (soaked curing) results against 5%, 10%, 15% and 20% wood ash and soil CL mixture.

ISSN 2229-5518

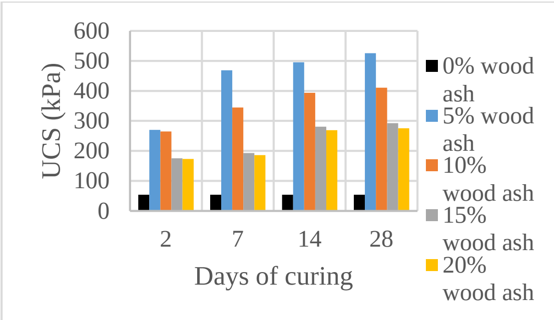

Chart- 6: UCS (soaked) results for CL

UCS soaked test results, untreated soil have UCS value of 54.2 kPa. With the addition of 5% wood ash UCS value increases to 270.0 kPa after two days, 468.5 kPa after 7 days and 525.4 kPa after 28 days of curing. For addition of 10% wood ash UCS value increases to 265.0 kPa after two days, 344.6 kPa after 7 days and 410.9 kPa after 28 days of curing. For addition of 15% wood ash UCS value increases to 175.4 kPa after two days, 193.1 kPa after 7 days and 292.4 kPa after 28 days of curing. For addition of 20% wood ash UCS value increases to 173.1 kPa after two days, 186.2 kPa after 7 days and 275.4 kPa after 28 days of curing.

The increase in unconfined compression strength during curing period is due to the formation of cementing gel materials produced due to the pozzolanic reactions which take place over a period of time. In pozzolanic reaction strength increases by forming silicate gel which initially binds and coats together the lumps of clay, with the period of time it forms crystals which binds the soil particles which result in the gain of strength (Terrel et al., 1979; Hadi et al., 2008).

$Ca(OH)_2$ -------------------------- $Ca^{2+} + 2(OH)$

$Ca^{2+} + OH^- + SiO_2$--------------CSH

$Ca^{2+} + OH^- + Al_2O_3$------------CAH

The main source of $Ca(OH)_2$ is wood ash which reacts with clay minerals found in soil. After 5% to 10% of wood ash content the UCS value decreases which may be due to the quick use of lime in the pozzolanic reaction while the additional quantity of wood ash acts as unbounded particles or filler which have no any cohesion or any friction which results in decrease of unconfined compression strength [3] [4] [6] [7].

2.3 California Bearing Ratio (CBR)

One point CBR test was performed according to ASTM D1883-14 for CL-ML and CL. Mold of 6" diameter and 7" height with 2" spacer disk was used. Samples were compacted in five layers with 65 blows each. Soaked and un-soaked samples prepared at OMC and MDD were tested.

From Chart no. 7 CBR un-soaked untreated CL-ML have CBR value of 6.6 %. With the addition of 5% wood ash CBR values increased to 10.0 %, with the addition of 10 % wood ash CBR value increases to 11.6 %, with the addition of 15 % wood ash CBR value increases to 10.3 % and with the addition of 20 % wood ash CBR value increases to 10.1%.

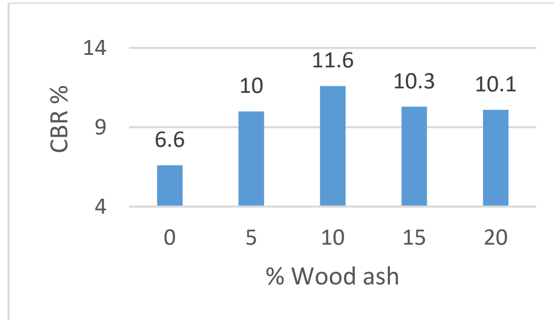

Chart- 7: CBR (un-soaked) test result on wood ash treated CL-ML

From chart no. 8 CBR soaked untreated CL-ML have CBR value of 5.4 %, with the addition of 5 % wood ash CBR values increased to 6.8 %, with the addition of 10 % wood ash CBR value increases to 8.5 %, with the addition of 15 % wood ash CBR value increases to 6.6 % and with the addition of 20 % wood ash CBR value increases to 5.8 %.

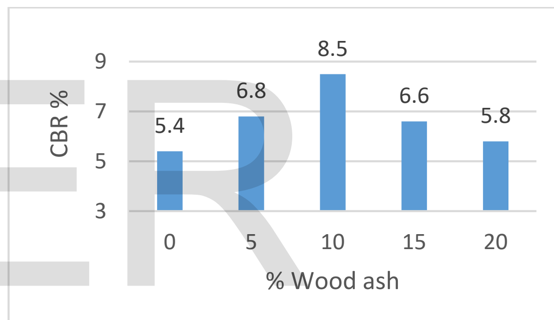

Chart- 8: CBR (soaked) test result on wood ash treated CL-ML

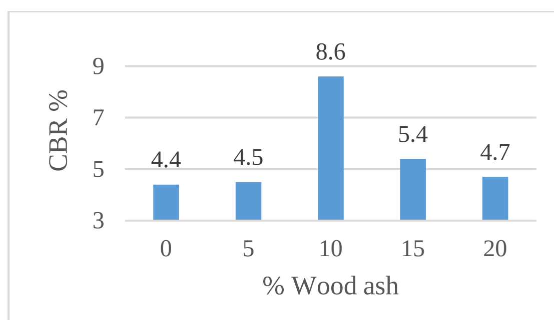

Chart- 9: CBR (un-soaked) test result on wood ash treated CL

From chart no. 9 CBR un-soaked untreated CL soil have CBR value of 4.4 %. With the addition of 5 % wood ash CBR values increased to 4.5 %, with the addition of 10 % wood ash CBR value increases to 8.6 %, with the addition of 15 % wood ash CBR value increases to 5.4 % and with the addition of 20 % wood ash CBR value increases to 4.7 %.

ISSN 2229-5518

From Chart no. 10 CBR soaked untreated CL soil have CBR value of 2.2 %. With the addition of 5 % wood ash CBR values increased to 2.7 %, with the addition of 10 % wood ash CBR

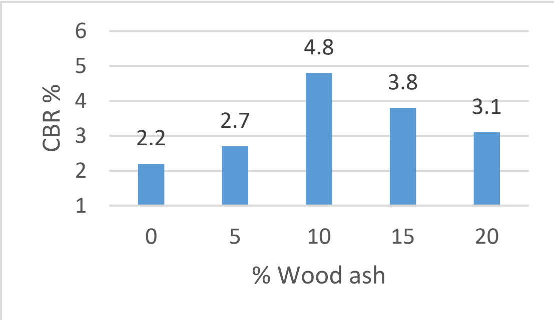

Chart- 10: CBR (soaked) test result on wood ash treated CL

value increases to value increases to 4.8 %, with the addition of 15 % wood ash CBR value increases to 3.8 % and with the addition of 20 % wood ash CBR value increases to 3.1 %.

Table- 1: Properties of untreated soil

PROPERTY	CL-ML		CL	
LL %	26.2		29	
PL %	20		17.1	
PI %	6.2		11.9	
Sieve # 200	71		90	
Clay Content %	17		22	
Specific Gravity G_s	2.51		2.67	
MDD g/cm^3	1.95		1.84	
OMC %	12.2		14.3	
UCS KPa	Soaked	80.2	Soaked	54.2
	Un-soaked	240.8	Un-soaked	255.4
CBR %	5.4		2.2	

Improvement in CBR value with the addition of wood ash is due to the soil lime reaction which forms flocks of soil, they retain their individuality when kneaded and compacted [1] [2]. Another reason for gain in CBR value is due to the formation of tetracalcium alumina hydrates and silicate hydrates which bond together clay particles [3] [4] Montohar & Hantoro, 2000; [5] [6]. Another reason for improvement of CBR value are due to the immediate cation exchange flocculation and agglomeration reaction.

3 CONCLUSIONS

This study was conducted to study the effect of addition of wood ash on soil from Skardu region and to see the improvements in physical and mechanical characteristics of soil. Following conclusion can be made from the finding of this research study:

Soil in Skardu Region varies from fine to coarser material (Silt to clay and sand to gravel). Soil selected in this study is low plastic Lean clay (CL) and Silty clay (CL-ML).

- Presence of clay minerals detected by XRD analysis shows that soil is reactive.
- For both types of soil, maximum dry density is decreased by the addition of wood ash while increase in optimum moisture content is observed. Decrease in dry density is due to flocculation of soil particles. Soil become more friable and difficult to compact. While the increase in optimum moisture content is due to the increased surface of soil particles due to the addition of wood ash which is finer particles. Higher the surface area, more water is required for wetting of soil particles.
- Change in UCS of soil with varying content of wood ash is observed. For soaked and un-soaked curing with 5% to 10% of wood ash mixed with both type of soils have higher strength. The improvement in UCS was associated with the improvement in chemical bonding between soil particles due to the pozzolanic reaction between soils minerals with pozzolanic agent present in wood ash.
- Improvement in CBR of treated soil under soaked and un-soaked condition is observed for both types of soil. At 10% wood ash mixed with both types of soil have higher CBR values. Increase in CBR may be due to the cementation between soil particles caused by wood ash.
- Based on results of laboratory testing, it can be concluded that wood ash improved the engineering properties of soil in Skardu region in an effective manner.

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