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SOIL STABILIZATION USING INDUSTRIAL WASTE (WHEAT HUSK AND SUGARCANE STRAW ASH)

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Abstract *The safe disposal of both hazardous and non-hazardous waste becomes a problematic for the civil engineers. This is because only few states are able to dump these wastes emanate from industries safely. This paper presents a research on safe disposition of industrial waste such as wheat husk ash (WHA) and sugarcane straw ash(SCSA). So, efforts have been made using WHA and SCSA in this research to revamp the quality of the soil. The main objective of the ground improvement is increasing the shear strength and decreasing the compressibility of the soil. The study was conducted using the expansive soil by taking varying quantities, which are then mingled with the different proportions of stabilized material for Atterberg limit tests and Unconfined compressive strength(UCS) test and soil retained within 7 days curing period for California bearing ratio(CBR) test. These tests are experimented and proved by the standard tests IS 2720 and finally concluded that test results ameliorate the geotechnical properties of the soil.*

Key Words: **CBR test, UCS test, soil sample, stabilization, black cotton soil, wheat husk ash and straw ash.**

1.INTRODUCTION

The basic construction material of the geotechnical engineer's design foundation is the soil. In many set of circumstances, road service layers, foundation layers and construction material cannot utilize the soil directly. The rising cost of the land, and huge demand for high rise buildings makes the improvement of soil at a site unavoidable. Therefore, it is required to revamp the quality of the soil. The expansive soil used in this research also known as black cotton soil. This soil is taken as it contains particles of montmorillonite, which absorbs water easily and thus, attains contraction and shrinking property. The humidify and scorch process of a subgrade layer comprised of black cotton (BC) soil which results into failure of pavements in form of colonization and rupture. Therefore, soil is binded to suppress the effect of such particle, which is responsible for the high percentage of expansiveness and cracks thus, it is dangerous for the construction. Therefore, it is important either to remove the existing soil and replace it with a non-expansive soil or to improve the important properties of the existing soil by stabilitate prior to construction of a road on such subjugate. The cost-effective practices like explore with industrial wastes are utilized to ameliorate the acreage of the soils having mucilage value. This is done by the process of soil stabilization. This process is mainly used where the available soil is not fit for the intended purpose, it requires to be remodel. The first experiment on soil stabilization was conducted in USA with sand or clay mixtures in 1906. The soil stabilization for road construction was done in thirties in Europe [1]. Many researchers attempt to use the industrial wastes like rice husk ash (RHA), fly ash (FA) are used to revamp the geotechnical properties of a soil [2]. However, the inclination of using the waste material is being used by all over the world nowadays.

1.1 Wheat Husk Ash(WHA)

WHA has a good pozzolanic property. It is used for various purposes. It is the staple food produced in large quantity for living and non-living beings. It has high calorific value of about 3.5 kcal/g. Its by-product is often found in the fields because waste is burned by the farmers after extracting grains. In this research, the effect of WHA on the soil is studied. Wheat husk is taken from the agriculture fields and burned at 600°C to convert into fine ash. This ash has highest amount of silica which helps in fertility of soil. Wheat husk ash, basically a waste material, is produced by burning crops waste while processing wheat from paddy. About 20 – 22% wheat husk is generated from paddy and about 25% of this total husk become ash when burn. It is non – plastic in nature. Its properties also varied depending on its burning temperature.

The chemical properties of WHA are shown in Table 1.

Table -1: Chemical properties of WHA at 600 °C

Sr. No.	Compound	Value (%)
1	Silicon Oxide(SiO_2)	43.22
2	Potassium Oxide(K_2O)	11.30
3	Magnesium Oxide(MgO)	0.99
4	Iron Oxide (Fe_2O_3)	0.84
5	Sodium Oxide(Na_2O)	0.16
6	Chromium oxide(Cr_2O_3)	0.0004

7	Calcium Oxide(CaO)	5.46
8	Manganese Oxide(MnO2)	0.02

1.2 Sugarcane Straw Ash(SCSA)

The chemical properties of SCSA is summarized in Table 2.

Table-2: Chemical Composition of Sugarcane Straw Ash

Sr. No.	Compound	Value (%)
1	Silica (SiO2)	70.20 %
2	Aluminum(Al2O3)	1.93
3	Iron (Fe2O3)	2.09
4	Calcium (CaO)	12.20
5	Magnesium (MgO)	1.95
6	Potassium (K2O)	3.05
7	Sodium(Nao)	-----

Sugarcane straw ash is also called bagasse ash. Sugarcane is used by many large industries and mills to make sugar by extracting juice. Sugar is used as a food product by every household person. The waste produced from these large mills creates disposal problem. There is about 30% bagasse produced from the crushed sugarcane (3). This bagasse is utilized by many researchers for soil stabilization due to fibrous material contained in it, which aids the soil to bind the particles of the soil together by reducing the void ratio and increasing their shear strength. The technique of using the bagasse ash of every researcher for calcination process is different.

1.3 Objective of the study

The main objective of the study is to enhance the quality of the soil using the flour nutshell ash and sugarcane straw waste. Addition of such material will enhance both physical as well as chemical properties of the soil. This research undertakes the use of agricultural waste in stabilizing black cotton soil, various attempts have been made to improve the strength of soil using different chemical additives in combination with straw ash. Therefore, by using agriculture waste various properties of soil are improved. The physical properties of soil include horizonation, color, texture, structure, consistency and bulk density. The chemical properties consist of soil cation exchange and soil reaction that is pH value. Chemical analysis was performed to identify the constituents of the cane waste and flour nutshell ash after burning at 600°C.

2. REVIEW OF LITERATURE

Many researchers attempt to stabilize the soil with the use of Cementous materials and agricultural waste as a combination.

Amit S. Kharade (2014) stabilize the soil by collecting bagasse ash from the sugarcane industry. This study solves the disposal problem of sugar cane because samples for stabilization was collected from sugarcane industry situated in Maharashtra. The bagasse ash contains the fibrous material in which silica is present. The laboratory tests such as CBR, UCS, compaction and Atterberg's test was conducted to find the potential of the stabilized material. Tests were conducted with partial replacement of different percentages and it is noticed that 6% bagasse ash surges the significant chemical, physical and geotechnical properties of the soil. In the initial study, it is concluded that black cotton soil has low compressibility and bearing capacity. With the addition of ash, the shear strength and bearing capacity strengthened. The resulted material vigor the flexibility of the black cotton soil [3].

Ajay Goyal (2007) conducted an experiment to find out the effect of wheat straw ash and rice husk on the strength properties of the ash after burning at the optimum temperature. Ash materials are burned at an appropriate temperature to extract the fibrous material to achieve the aim. Therefore, under controlled temperature only 10% ash was occupied. Compressive and flexural strength test was conducted to verify the relative quality and strength development of mortar. The results concluded from the experiment shows that addition of wheat ash and rice ash is optimum to synergize the mortar. The reason behind improvement is the optimization of pozzolanic and filler effect. Moreover, the significant improvement was examined due to the presence of wheat straw ash [4].

Humberto (2007) quantified the research on finding out the bond between the crop residue and soil which shows alterations in soil organic carbon(SOC) concentration. Thus, addition of ash alters the properties of the soil by the process of mulching which shows that straw mulching with soil retains the soil organic carbon for longer times. This research focuses only on segregating soil organic carbon, increase the tensile strength and didn't increase the shear strength. This is because 2/3 of wheat straw ash doesn't converted into SOC.Thus, mulched soil shows higher amount of carbon in contrary to non-mulched one [5].

Andrzej k. Bledzki (2010) investigate the potential of wheat husk for reinforcement in plastics by the scanning of electron using microscope. The materials incorporated in this research includes wheat husk and rye husk. The thermal, physical property was measured and analyzed by the instruments and chemical contents contained in the mixture were investigated by the electron microprobe analyzer. The improvement is due to the soft wood material in the particle size distribution range 100-200 micrometer. The impact strength and tensile strength was investigated which concludes that wheat husk contain more silicon surface than other materials [6].

Amu (2011) determines the geotechnical properties of the soil by adding sugarcane ash as a stabilizer and experimenting various tests which includes CBR test, moisture content test, specific gravity test etc. The soil used here is the lateritic soil for the experiment. The pozzolan material having Cementous value at a particular temperature. The plasticity index of the soil was reduced for the different samples which exhibits the indication of soil improvement. Moreover, the CBR value was 400% higher than unstabililized samples for A and C and 220% for sample B. The sample strengths rose from 79.64 to 284.66kN/m2, 204.86 to 350.10kN/m2 and 240.4 to 564.6kN/m2 in samples A, B and C respectively. Thus, unconfined compression strength is the fundamental determinant of consistency of a clayey soil. The results of the test strengthen the research which demonstrates that cane ash is an excellent stabilizer for the soils which are rich in iron and aluminum in soils [7].

M. Chittaranjan, M. Vijay, D. Keerthi (2011) studied the 'Agricultural wastes as soil stabilizers'. In this research, sugar cane bagasse ash, rice husk ash and groundnut shell collected from the industry are used to stabilize the weak sub grade soil. The given soil is mingled with the given three wastes separately at 0%, 3%, 6%, 9%,12%and 15% and CBR test is carried out for each per cent. The results of these tests showed revamp in CBR value with the inclined percentage of waste [8].

Nazar Omer Hassan Salih (2012) researched on the fertility of the soil by using wheat residues over the all seasons of the crop yielding. The results of the study are marvelous which shows that crop fertility in the field of residual crop is more as compared to the no residue soil [9].

Pinar Terzioglu (2012) uses the wheat husk ash to produce the magnesium salt using the Fourier transform series. This research is done to solve the waste problem and contribute enormously in the recovery of industries. Wheat husk is burned at an optimum temperature then it is chemically reacted with the sodium hydroxide with flame to extract the silica. The obtained ash was composed of different elements and silicon dioxide has the highest percentage consists of 44%. Thus, obtained ash has completely amorphous structure. This element is suitable to synthesize the required outcomes. The research proves that study does not affected the chemical composition of the magnesium silicate [10].

Ogunribido(2012)utilizes the wheat straw ash for the stabilization of some soils. He basically stabilized soil by collecting different samples of soil from different locations. The quantity of wheat straw ash ranges from 2 to 10% to analyze the properties of the soil like specific gravity, compaction, California bearing ratio, shrinkage limit etc. The results are amazing which concluded that prior to the addition of the cane ash the tests are poor but adding the ash as sub grade material ameliorates the geotechnical properties of the soil. He concluded that bagasse ash is not good stabilizing material for the lateritic soil [11].

Ogunniyi Jumoke Esther (2013) noticed the positive outcomes of the incorporating the wheat straw ash in the cultivated fields. The soil was treated with different nitrogen sources to investigate the quality of the soil. The incorporation of straw always has positive result but here the problem is the rate of decomposition gets slow. The main reason behind this is the Carbon to nitrogen ratio. Thus, experiment conducted which consists of17 pots with four imitations. Each pot containing 150 gm of soil and 1.125 gm of straw and the moisture content adjusted to 80% of the field ability. The addition of wheat straw resulted in higher microbial biomass accumulation in contrary to maize straw [12].

Isak R. Shaikh (2013) conducted research using wheat husk straw. The sample was prepared at the room temperature. The MCM-41 type sample is used here to extract the silica. This silica is beneficial as it is a fibrous material useful for reinforcement. The researchers in this paper focus to bring forth development of chemical technologies which aids the ecological and environmental health on the planet. This can be done by identifying and implementing scientific trends in utilization of biomass and valorization of ashes. The aim of the future work is to develop the catalyst which are environmental friendly from chlorides using this silica material. The conducted experiment proves successful of collecting ashes from the power stations have a great help in recycling industrial waste [13].

Shamle, N.J(2014) extracted the silica from the different industrial ashes using the fluorescence spectroscopy. The amorphous silica is taken from the acha husk, wheat husk and rice husk ash by the process of calcination. These are used as raw material. Thus, obtained silica is conglomerate with the sodium hydroxide and it is obtained by lowering the pH value. The isolated amorphous silica from these ashes are compared to find the better one in this paper. Finally, it is concluded that out of three ashes, acha husk ash is a suitable material with minimum impurities and gives the highest yielding [14].

S. Manimaran (2015) presents the study on the usage of bagasse ash to stabilize the black cotton soil. This is taken from the Tamil Nadu region where soil possesses weak properties which results into failure of foundations and pavements. The whole process is natural and thus fibrous material is obtained after experimentation. The optimum moisture content and maximum drying density was measured which is good for replacement 6% bagasse ash. The experiment is conducted using the different proportion of the ash replaced with the soil. The replacements are 0%,3%,6%,9% and 12% of ash. The strength tests are carried out with each blend and results are concluded by IS 2720. The results are based on MDD, OMC, CBR and

compressive stress test which proves successful to stabilize the soil [15].

Mr. Santosh (2015) conducted an experiment using the wheat husk ash and slag, which is a by-product of the iron industry, from the blast furnace. This is because stabilization using admixtures are more advantageous than the mechanical, cement, lime, bituminous and earth reinforcement method. The major reason for stabilization is that black cotton soil contains special mineral which absorbs water. This gives shrinking and contraction to the pavements which is seen in the form of cracks. So, research is conducted to stabilize the expansive soil by adding admixture. The main focus is on the use of the industrial waste. Here, potential of the applied material is checked by the specific gravity, grain size distribution, liquid limit, plastic limit, UCS and standard proctor test. The compaction test was modelled by stress vs number of days. The results showed that adding 9% of WHA and GBS to the soil decrease the water content up to a limit. This research is suitable and gives most effective results on 7 days curing period. Thus, 9% is an optimum percentage to enhance the properties of the required soil [16].

Jiguang Zhang (2016) investigates the tobacco field by analyze the effects of incorporating straw in the soil. The wheat and maize straw was collected from the Zhuchengarea of Southeast Shandong province for three years. The soil here is treated with seven treatments such as no straw, use the both straws in middle level, and use it at higher level. The value of the nutrients is measured and organic fertilizers are laid down on the fields each year. However, soil organic carbon and other related parameters were revamped by the incorporation of the both wheat and maize straws. The study reported on the field's shows that maize straw is more successful than wheat straw in improving the soil enzymes. This is because maize straw increases the soil aggregate stability of the soil. Moreover, the value of SOC and its nutrients was more in case of maize incorporation. [17].

Arunav Chakraborty (2016) examines the soil very closely which poses threat to the civil engineers. Here, cost effective method sugarcane straw ash is used to stabilize the expansive soil. Stress is more given on to enhance the geotechnical properties by varying curing periods and percentages of admixtures. Already, enough work is done by using cane ash but here different proportions of straw ash are taken by testing on different days. Thus, various tests are investigated such as CBR, UCS, Atterberg limits, sieve analysis, proctor and CBR value. The Unconfined compressive strength test was conducted on 3, 5 and 7 day curing period. The results represent that the increase in curing period surges the UCS value. However,10% addition of admixture gives the maximum CBR value [18].

Tiza Michael, Sitesh Kumar Singh and Anand Kumar (2016) highlights the work done by different researchers for soil stabilization. The methods and material used by them to stabilize the soil to potent by the CBR, UCS, plasticity index etcetera tests. Different materials such as cement kiln, red mud, copper slag, and brick dust, polyvinyl waste, ceramic dust and fly ash was studied in this article. The CBR value is computed by analyzing the results using different waste materials. The researchers taken into consideration the use of only the material. The mineral content for longevity and durability is considered minimum. But all the methods able to convert the expansive soil into non-expansive soil [19].

3. METHODOLOGY

Wheat husk and sugarcane straw was firstly washed thoroughly with distilled water and then dried under sunlight for 24 hours within 49°C temperature. The dried straws are heated and burnt in a preheated oven at 600°C separately as shown Fig. 1. The obtained ashes are then experimented for various tests and retained under curing period of 7 days for CBR test.

3.1 Preparation of the sample

1. The pulverized soil sample was first sieved through the required sieve for a particular test.
2. The required quantum soil was weighed out for the test.
3. The material to be added to the soil was also sieved through the required sieve, for the particular test and then the required quantum was weighed out on the weight basis as per the percentage to be added to the soil for test.
4. Then, black cotton soil was kept in oven for removing moisture content and drying at 110°C temperature for 24hrs is done. Then the agricultural waste ash is also kept in oven for maintaining the dry form of the ash.
5. For different blend mixtures, the ash content was taken according to certain percentages by weight of soil and it is mixed with soil in dry form itself. Similarly, for the blend mix with WHA and SCSA, all the materials are taken in dry form and mixed. The results are analyzed according to the standard [19] and on this basis the synergic effect is taken into account by replacing ternary blends of WHA and SCSA ratios such as (3+3%), (5+5%), (9 +9%), (7+7%) and (11+11%).The mixed sample was then used for performing the various tests.

In this research, remolded expansive clay was blended with WHA and sugarcane straw ash and strength tests were conducted. The potential of WHA blend as a swell reduction layer between the footing of a foundation and sub grade was studied. In order to examine the importance of the study, a cost comparison method was made for the preparation of the sub-base of a highway project with and without the admixture stabilizations. The strength parameters like CBR, UCS are determined to know the suitability of material. It is

found that results of soil replacement by both WHA and SCSA proved to be soil modification and not the improvement.

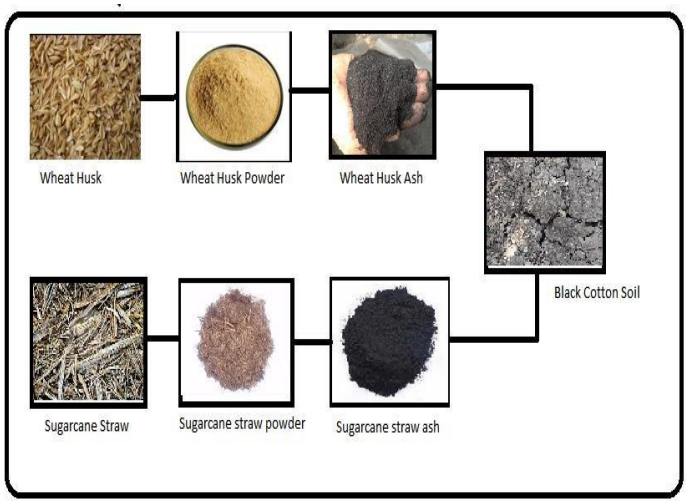

Fig -1: Block diagram of stabilization of the soil

4. RESULTS AND DISCUSSIONS

4.1 Maximum drying density(MDD) and Optimum moisture content(OMC) relationship

Proctor test has been conducted to evaluate the correlation in between MDD and OMC. Improvement in the maximum dry density was observed slowly for 3% and 7% with replacement of bagasse ash and WHA ash, but then after further increase in blend MDD decreases. This decrease may be due to low specific gravity bagasse ash replaces higher specific gravity soil as, it is fibrous in nature.

Table -3: MDD and OMC using different proportions of WHA and SCSA ashes

Replacement of stabilize material (%)	Pure Black cotton soil		Black cotton soil + WHA+SCSA	
	MDD	OMC	MDD (g/cc)	OMC (%)
0%	1.415	25.12	NIL	NIL
3%	-	-	1.23	34
5%	-	-	1.42	30
7%	-	-	1.48	27
9%	-	-	1.33	24
11%	-	-	1.26	20

It was observed that as proportion of bagasse ash increases the optimum moisture content decreases in table 3.

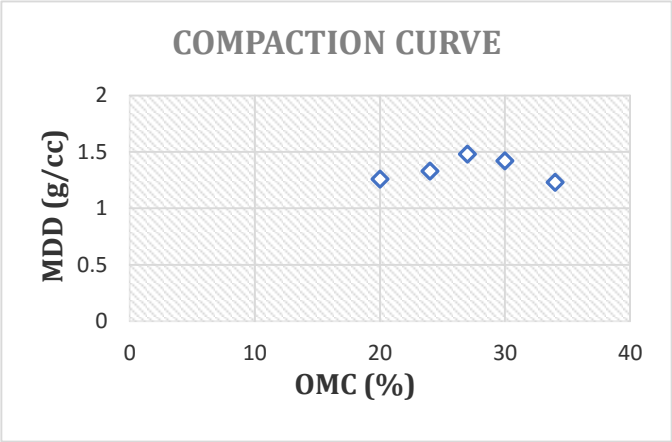

Fig -2: Compaction curve in between OMC and MDD

The compaction curve in Fig 2 rendered that maximum OMC was achieved with 7% addition of additives. This gives maximum drying density at this proportion.

4.2 Atterberg Limits

The plasticity of the soil is the ability of the soil to mould into many shapes when the soil is wet. This is basically due to the presence of clay minerals. So, when the soil is wet it is attracted towards water molecules. So, this plasticity is due to adsorbed water. The Atterberg limits show that soil having plasticity and it has clay minerals and purely suitable for the embankments as shown in Fig 3.

Table -4: Atterberg limits as soil mix with WHA and SCSA

Percentage of Enhancement (%)	Black cotton soil + different percentages of WHA & SCSA		
	Liquid Limit	Plastic Limit	Plasticity Index
3%	36	21	15
5%	37	24	13
7%	39	23	16
9%	30	21	9
11%	32	19	13

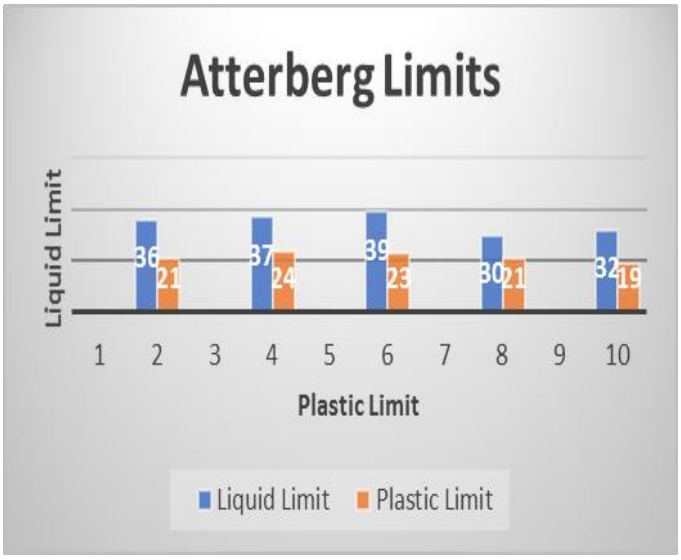

Fig -3: Liquid limit vs plastic limit shows Atterberg limits

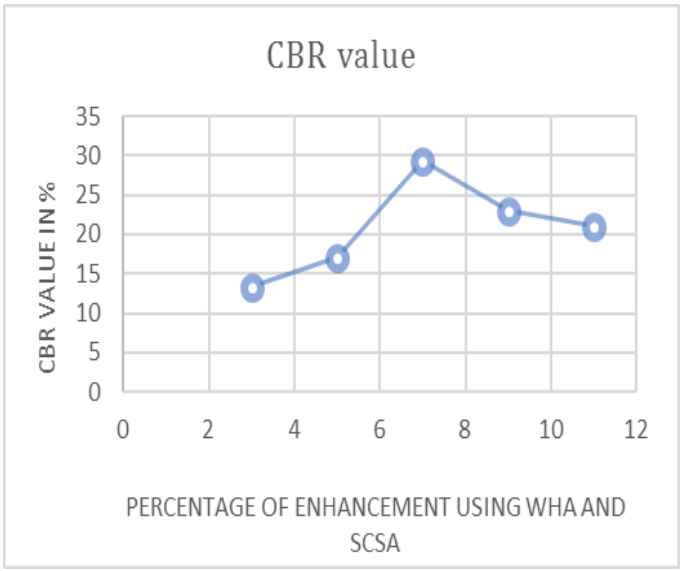

Fig - 4: Effect of soaked WHA and SCSA ashes on CBR value of the soil

4.3 California Bearing Ratio

CBR value is used to check the shear strength and bearing capacity of the soil. Two types of test are performed to calculate the CBR value. In this test, soaked sample is used, which gives the revamped CBR values.

The graph 3 shows that at low energy levels bearing ratio is very less and therefore less water is available for controlling the hydration process. But as the percentage of ashes increases there is increase in CBR value. It again decreases at certain optimum value. Thus, it is clear that 7% addition of both ashes gives more consistent results.

Table- 5: Effect of soaked WHA and sugarcane straw ash on CBR Value

Percentage of Enhancement (%)	Black cotton soil + different percentages of WHA & SCSA
	California Bearing Ratio (CBR values) soaked
3%	13.33
5%	17.08
7%	29.33
9%	23
11%	21.02

4.4 Unconfined Compressive Strength

The compressive strength was conducted to calculate the undrained shear strength. This is basically equal to the half of the undrained shear strength.

The soil sample prepared for the test are analyzed based on the given table 6. The different percentages of the wheat husk and sugar cane straw ash was mixed with the raw soil to revamp its quality. It is seen in the given graph 4 that maximum strength was obtained at 7% which was about 357.65. This compressive strength was used to calculate the undrained shear strength.

Table-6: Variation of UCS with application of WHA and sugarcane straw ash

Percentage of Enhancement (%)	Black cotton soil + different percentages of WHA and SCSA
	Unconfined Compressive strength (UCS values)
3%	287.58
5%	288.8
7%	357.65
9%	268.03
11%	233.59

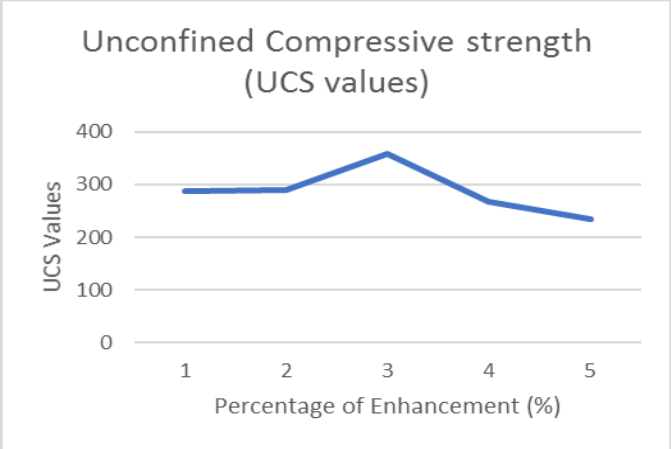

Fig – 5: Effect of WHA and SCSA to measure UCS value of the soil

5 CONCLUSIONS

The study reveals that the inclusion of wheat husk ash and sugarcane straw ash gives more consistent results as compared to the individual addition to the specimen. The values obtained after plethora of experimentation clears that these values are used as index for the designing and laying the base and sub base material for the infrastructure development and pavements structuring. The research determines the following investigations carried out in the laboratory are as given below: -

1. The collected black cotton soil has specific gravity is very less. This is basically due to fibrous nature of the soil. The mixing of different proportions of both ashes to the black cotton soil shows that there is improvement in MDD in addition of 5% and 7% and then further decreases due to stiffness of the soil.
2. The optimum moisture content was attained at 7 % and then further there is sharp decline. This OMC is used as an index to mix the quantities together for various projects.
3. The Atterberg limits of pure black cotton soil shows that the collected soil is highly plastic in nature as its plasticity index is more than 17. The differ in percentages of enhancement at 7 % addition of both ashes renders that soil shows clayey nature. This nature is fruitful to the applying soil for the pavements.
4. CBR value is utilized broadly by many engineers and researchers in design of sub base material for building construction. This value is used as index parameter to determine the bearing capacity and shear strength of the soil. It is maximum at 7 percent enhancement level and then further decreases. This decline is basically due to certain increase and decrease in OMC which is responsible for decrease in CBR value.
5. The UCS test gives the shear strength as an index to structuring the buildings by various engineers. It is clear from the above results that the strength increases slowly with the addition of ashes and then maximum strength is at 7% addition

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