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Assessment of Expansive Properties of Soils and Remedial Measure Through Wooden Ashe Stabilazation in Bellessa Town, Ethiopia

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ABSTRACT

Expansiveness is a phenomenon that affects many clay soils, particularly those that contain significant quantities of montmorillonite clay minerals. The study area is covered by such expansive soils that infrastructures are possibly under considerable problem due to these soils sixteen soil samples from eight pit were taken for both field tests and laboratory investigations. Field moisture content and field density tests were conducted. Laboratory tests revealed that the natural moisture content ranges from 22.80-32.75% specific gravity of the soil's ranges from 2.62 to 2.85. Results of Atterberg limits tests of all soil sample shows that fine soils have liquid limits range from 53.48 -78.16%, plastic limit ranges from 12.31-21.35% and plastic index from 36.14-57.54% these values indicate that the plasticity of the soils of the study area is high plastic. The grain size distribution indicates that most of the soil samples have fine material more than 50% passing 0.075mm. Therefore, fine grained of soil is dominantly located in the study area. The free swell test result range from 55-90% indicates that soils of the study area were expansive which means degree of swell of the soils was greater than 50% having high swelling. The degrees of activity of most of the study area soils are active with values of activity greater than 0.83. USCS indicates main type of soils, which is highly plastic clay soil (CH). According to AASHTO classification soils of the study area is A-7-6, which means clay soil with poor quality as a subgrade material. The Compaction test results showed that maximum dry density (MDD) of the study area ranges from 1.29 to 1.49gm/cm^3 and the optimum moisture content (OMC) ranges 26.13 to 39.79%. The unconfined compressive strength test results of the study area were ranges from 55.98-158.08 KN it indicated that stiff to very stiff clay. Finally, one-dimensional consolidation tests were done and have compression index ranging from 0.13-0.35, recompression index ranging from 0.008-0.092. The contribution of wooden ashes to the Liquid limit, Plastic limit, Plasticity index, coefficient of compression, coefficient of recompression, swelling potential and the Swelling pressure decreases with increasing wooden ashes contents and while maximum dry of soil increases with increase wooden ashes. Increase wooden ashes increase shear strength of soil until it reaches peak point then decreasing shear strength of soil. So, wooden ashes are blended with expansive soil the highest (optimum value) were obtained at 10% of wooden ashes. The higher wooden ashes content the greater the strength, which helps in increasing bearing capacity of expansive soil until it reaches maximum value of ashes.

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Introduction

Expansiveness (also referred to as reactivity) is a phenomenon that affects many clay soils, particularly those that contain large quantities of highly plastic clay minerals. In many cases, the shrinking and swelling of expansive clays in response to moisture content change can be a serious cause of damage to residential building [1]. Foundation materials, that exhibit volume Changes caused by changes in soil moisture are called swelling or swelling clays. Characteristic expansive or swelling materials are highly plastic clays and clay shales that often contain colloidal clay minerals such as the montmorillonites [2].

Expansive soils are found in large areas of the world including southwest and western United States including Oklahoma, Texas, Colorado, Nevada, California, Utah, and others. These soils are also found in large areas of India, and Australia (sometimes called black cotton soils), South America, the Middle East and Africa. Eastern African occurrences are by far the most widespread in Africa. Large parts of Ethiopia and Sudan are covered with black clay soils, as are smaller areas in Tanzania, Kenya, Uganda, Malawi, and Zambia. The associated volcanic rocks are the main cause of the black clays' formation in Ethiopia, Kenya, and Sudan. Most of the Ethiopian plateau and part of the Somalia plateau are covered with tropical black clays [3].

Engineering problems due to expansive soils have been reported in many countries all over the world, costing millions of dollars due to severe damages of structures. These damages are most common especially in the arid and semi-arid regions. Damages are usually manifested through crack of floors and walls, stacked windows and doors, bulged floors and tilted walls and structures. The magnitude of the damages can be extended even to the extent of failure of one or all structure by decreasing the structural safety of the building. Maintenance and repair cost can also exceed the original cost of the foundation and creates financial burden to the owner. Due to this Balesa town area have problem which any structure would fail in each year. Soil stabilization using chemical additives such as cement, rice husk ash (RHA), fly ash, and lime is widely used because of their cementitious constituents modify and stabilize soft soil through cation exchange, flocculation and agglomeration, and reactions.

However, the selection of chemical additives depends on several factors such as dry density, shear strength. Wood that widely used as a fuel and energy sources has led to a strong increase in the amount of combustion residue. Wood ash is a grey material produced from the combustion of wood. It is generally discarded as waste and dumped Outside of house or landfill, which increase the volume of landfill.

Material and Methodology

Back Ground of Study Area

Balesa is one of the towns located in Hadiya zone of SNNPR state of Ethiopia. The town is one of the fast-growing towns in SNNPR, Hadiya zone, Lemo woreda. The town consists of administrative, commercial, and residential areas as well as surrounded by agricultural land. The total area of the city covered by Master Plan is 325 hectares. This town geographic location has a latitude and longitude of 7°59′North, 37°97′ East respectively and an average elevation of 2299 meters above sea level. The topography of the town is almost flat. The temperature of the town is 15.1°C- 20°C The town is along Addis Ababa- Butajira Hosanna Wolaita Soddo road at a distance of 228Km south from Addis Ababa and 200 Km from the regional Capital city, Hawassa and 6 km west from Hosanna. The town is found along the street of Fonko town which Fars 4km from Belesa

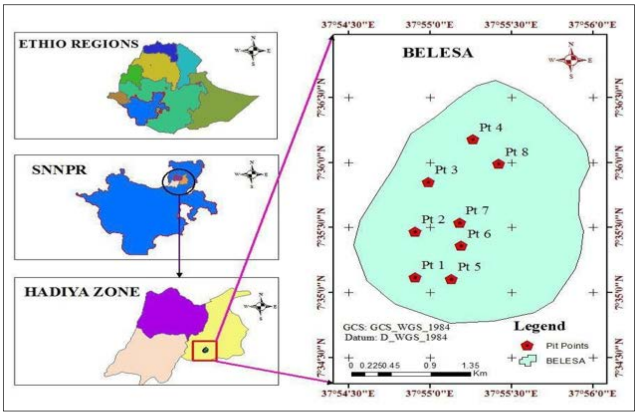

Figure 1: Location of Test Pits Samples Was Taken on Each Pits

Methodologies

In order to achieve the objectives of this thesis work eight sampling areas (8 pits) was selected (i.e. according to the broadness of villages of the town). From the selected sampling areas subsurface exploration would perform by boring test pits up to 3-meter depth beneath existing sub grade manually. From this meter depth depending on the number of layer 16 number of samples was collected. Disturbed and Undisturbed samples of soils was collected for laboratory testing. In order to take undisturbed samples for engineering properties like Unconfined Compressive tests, one-dimensional consolidation tests, need special care but naturally getting pure undisturbed sample was generally difficult. However, I would take special care in the pitting, catching & transporting work on every opportunity. Wood flour was collected from the locally available and was simply burned to prepare ash. 10kg wood ashes flour was collocated wood were used as fuel to start and maintain the fire. wood ash contained addictive behavior, which is the key factor for improving soil properties

Field Works

Field Identification of soils

Soils that can exhibit high swelling potential can be identified by field observations, mainly during reconnaissance and preliminary investigation stages. Important observations included:

- By visual inspection
- Wide or deep shrinkage cracks
- When in dry season it may be high strength & in moisture season low strength.
- Stickiness and low traffic ability when wet.
- Appearance of cracks in nearby structures. In situ tests would be applied. Like
- In situ density (Bulk Unit weight of soil).
- In situ water content determination.

➢ 8 sampling points would be selected.
➢ 10 kg wood ashes flour was collocated from different house which used as fuels
➢ Field GPS (Global position system) readings were taken to locate the ordinate of sampling area.
➢ The excavation work was conducted on selected 8 (pits) sampling areas by daily laborers using local digging equipment and from the selected sampling areas.

Then, from the samples collected the following laboratory tests was done. Atterberg limit tests (liquid, plastic & shrinkage limit), Grain size analysis (sieve & hydrometer test), Specific gravity test, Free swell test, Linear swell test, Standard compaction test. Unconfined compressive strength test and One-dimensional consolidation test. The tests conducted and soil classification performed by AASHTO (American Association of State Highway and Transportation Officials), and USCS (unified soil classification systems).

The In-situ Unit Weight

The in-situ unit weight refers to the unit weight of a soil in the undisturbed condition or of a compacted soil in-place. Determination of in-situ unit weight is made on borrow-pit soils so as to estimate the quantity of soil required for placing and compacting a certain fill or embankment. During the construction of compacted fills, it is standard practice to make in-situ determination of a unit weight of the soil after it is placed to ensure that the compaction effort has been adequate. Two important methods for the determination of the in-situ unit weight are being given Sand- replacement method and Core cutter method

Laboratory Tests

The entire laboratory tests are performed in geotechnical laboratory using the following standard testing procedures in table 1.

Table 1: Standard Testing Procedure (USCS).

Test Description	Standard Testing Procedure
Water content	ASTM D 4318-98
Atterberg Limits	ASTM D 2216-98a
Grain Size Distribution Analysis	ASTM D 1140-97 and D 422-98
Specific Gravity	ASTM D 854-98
Unconfined Compressive Strength	ASTM D2166-98a

Index Properties

Water Content Determination

The test was performed to determine the water (moisture) content of soils. First the soil sample was taken from the test pit and, the soil sample was sealed using polyethylene plastic and taken to the laboratory. Then the sample was transported to the laboratory for oven dry. For each test pit depth three trial was done in order to be accurate than the average value was taken. The water content is the ratio, expressed as a percentage, of the mass of "pore" or "free" water in a given mass of soil to the mass of the dry soil solids. According to ASTM, moisture content tests were performed in laboratory. Tests were conducted in oven dried condition for the study area. Keeping the soil sample in the oven for 24hr duration and at the average temperature value of 105 °C. Heating to a higher temperature would drive off some more water, but the tests were performed at this standard temperature. It was conducted about three trials for each sample and weighted average to obtain the good results [4].

Grain Size Analysis

The grain-size distribution of mixed soils was determined by combined sieve and hydrometer analyses. The conduct the sieve analysis 1000gm of air-dried soil was weighed and soaked. After 24hours the soaked soil was washed on sieve (0.075mm). Then the soil passed the sieve (0.075mm) was prepared for Hydrometer analysis and the soil retained on the sieve (0.075mm) were done sieve analysis. From the values particle size distribution curve was done for both Hydrometer and sieve analysis [5].

Atterberg Limits

The main purpose of this test is to determine the plastic and liquid limits of a fine-grained soil. The liquid limit (LL) is arbitrarily defined as the water content, in percent, at which a part of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm. When subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The plastic limit (PL) is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm diameter threads without crumbling (ASTM D 4318). A. Atterberg, a Swedish Soil Scientist, in 1911, formally distinguished the following stages of consistency– liquid, plastic, semi solid, and solid. The water contents at which the soil passes from one of these states to the next have been arbitrarily designated as 'consistency limits'–Liquid limit, Plastic limit and Shrinkage limit, in that order. These are called 'Atterberg limits' in honors of the originator of the concept [6].

Linear Shrinkage

A soil about 150 gm in mass and passing through a 425mm sieve was taken in a dish. It was mixed with distilled water to form a smooth paste at water content greater than the liquid limit. The sample was placed in a brass mould, 140 mm long and with a semi-circular section of 25 mm diameter. The sample was allowed to dry slowly first and then in an oven. The sample was cooled and its final length measured.

Specific Gravity

Specific gravity was performed to determine the specific gravity of soil by using a pycnometer. First the weight of the empty clean and dry pycnometer, W1 was measured. Then about 20g of a dry soil sample passed through (425micron) was placed in the pycnometer. After that the weight of the pycnometer containing the dry soil, W2 was31 determined and recorded. Then distilled water added to fill about half to three-fourth of the pycnometer. The sample was soaked for 10 minutes. Partial vacuum to the contents was applied for 10 minutes, to remove the entrapped air. The vacuum line was stopped carefully and removed from pycnometer. The pycnometer was filled with distilled (water to the mark), clean the exterior surface of the pycnometer with a clean, dry cloth and the weight of the pycnometer and contents, W3 was determined. The sample was removed from the pycnometer and was then pycnometer was cleaned. Then filled with distilled water only (to the mark). The exterior surface of the pycnometer was cleaned with a clean, dry cloth. Determine the weight of the pycnometer and distilled water, W4. Finally, the water was removed and pycnometer was cleaned (ASTM, 2000).

Free Swell Test

To perform this test, a 10 cm^3 (Vi) dry soil passing thorough a (425micron) sieve was poured into a 100 cm^3 graduated cylinder filled with water. The volume of settled soil was measured after 24 hours which gives the value of Vi. The ratio of the increase in volume to its initial, (Vf - Vi)/ Vi expressed in %, was taken as the free swell [7].

Engineering Properties

Standard Compaction Test

This laboratory for standard compaction was performed to determine the relationship between the moisture content and the dry density of a soil for a specified comp active effort. For this specific work Standard Proctor Test was used. First the air-dried soil sample was sieved on 4.75mm sieve. Then 3kg of soil sample was taken. The soil was compacted by a 2.5kg hammer falling a distance of one foot into a soil filled mold. The mold was filled with three equal layers of soil, and each layer was subjected to 25 drops of the hammer. Continuous trial was taken until the mass of the mold and wet soil starts to decrease. From each trial moisture content was determined. Then moisture content versus dry density graph was plotted to determine the maximum dry density and optimum moisture content of the soil (ASTM, 1698).

Permeability

The permeability of a soil is a measure of a how easily fluids (usually water) pass through the soil and is related to degree of to which the pores spaces of the soil connected to each other. The permeability of a particular soil is defined by coefficient of permeability, K. The permeability of the soil is geologically controlled by factors such as the shape minerals grains in the soil, the grain shape and size, the manner in which the shape the grains are held together, soil porosity, density and viscosity of inside soil, degree of soil saturation and type of flow inside the soil.

Consolidation Test

This test was performed to determine the magnitude and rate of volume decrease that a laterally confined soil specimen undergoes when subjected to different vertical pressures. For this particular research undisturbed samples were taken by ring sampler and the sample was placed on the consolidation ring from undisturbed sampler and cut the sides of the sample to be approximately the same as the outside diameter of the ring. A sample diameter of 63mm and 20mm were conducted for determination of Cc and Cr. The loading pressures applied were 25kPa, 50kPa, 100kPa, 200kPa, 400kPa, 800kPa and 1600kPa. The unloading pressures were 1600kPa, 400kPa, 100kPa and 25kPa. The dial gauge readings were recorded for 24 hours. From the measured data, the consolidation curve (pressure-void ratio relationship) was plotted. This data is useful in determining the compression index, the recompression index and the pre-consolidation pressure (or maximum past pressure) of the soil. In addition, the data obtained can also be used to determine the coefficient of consolidation and the coefficient of secondary compression of the soil form the consolidation curve pressure (log scale)- void ratio relationship the pre-consolidation pressure, swelling potential and consolidation pressure were calculated graphically (ASTM D 2435).

For Improving Soil to Know What Effect Came Due to Ashes
Soils and wood ashes were kept in an oven at 105°C overnight to remove moisture and repress microbial activity. The pulverized soil and ash contents were mixed manually in a large tray in a dry state with proper care because there is a possibility of non-uniform mixing.

To study the influence of the wood ash on the mechanical properties of the treated samples, it is crucial to maintaining consistency between the sample preparations. That consistency among the samples could be achieved by controlling the mixing water. In this investigation, samples were prepared using their corresponding optimum moisture content (OMC) in order to maintain the consistency. A series of laboratory test was conducted including index testing, compaction test, UCS test, direct shear test, and consolidation test on non-treated, as well as, ash-treated soils. Before conducting the compaction test, the non-treated and ash-treated soils (2.5%, 5%, 7.5%, 10%, and 15% ash content) were mixed with water for about ten minutes by hand. After that, the mixtures were put into large pan and mixing was continued by shaking, overturning, and pressing the bag to squeeze out the air from the soil voids. A series of standard Proctor tests for compaction and Atterberg limit test ash-treated soils were conducted according to ASTM D 698, ASTM D854, and ASTM D-4318, respectively. The specimen was then statically compacted in three layers inside a cylindrical split mold, which was lubricated so that each layer reached the specified dry density. The top of the first and the second layers was slightly scarified. After the molding process, the specimen was immediately extracted from the split mold. The samples were then sized as per required for different tests and placed within the plastic bags to avoid significant variations of moisture content before testing. Unconfined compression tests have been used in most of the experimental programs to verify the effectiveness of the treated soil. The uncured unconfined compressive strength of the cylindrical specimens (36 mm diameter and 71 mm length) was determined according to ASTM D-2166. The settlement characteristics of soils were determined by performing the consolidation test (ASTM D-2435) on the samples of 63.5 mm diameter and 25 mm height.

Results and Discussion
In this study, to determine the index and engineering properties of expansive soil were used to Assessment of Expansive Properties of Soil to minimize the failures of structure which building of earth surface for economical foundation design. All results based on the laboratory tests were carried out in accordance with the ASTM procedures for soil testing.

Field Test Work, In Situ Moisture Content and In Situ Density Determination
In this study, natural moisture content of the soil is determined in the laboratory by using undisturbed sample. In the laboratory this test is done by referring ASTM D2216-98 standard. Two trial moisture specimens from each test samples were taken and placed to dry them in an oven for 24 hours with a standard temperature of 1100c. Moisture content measurement is used for performing weight-volume calculation in soils. The bulk density of the soil was done on the site by core- cutter method. Moisture content of the test pits and bulk density are presented in Table 2.

Table 2: Moisture Content Results

Location	Natural water contents (%)	Bulk Density (g/cm^3)	Dry density of soil (g/cm^3)	Bulk unit weight (kN/m^3)
TP-1 @1.5m	32.75	1.70	1.28	14.98
TP-1 @3m	30.51	1.79	1.37	15.77
TP-2 @1.5m	31.69	1.65	1.25	14.54
TP-2 @3m	30.42	1.75	1.34	15.42
TP-3 @1.5m	30.69	1.67	1.28	14.71
TP-3 @3m	29.22	1.72	1.33	15.15
TP-4@1.5m	32.57	1.75	1.32	15.42
TP-4 @3m	31.68	1.78	1.35	15.68
TP-5 @1.5m	30.53	1.64	1.26	14.45
TP-5 @3m	29.31	1.77	1.37	15.59
TP-6 @1.5m	22.8	1.66	1.35	14.62
TP-6@3m	20.36	1.71	1.42	15.07
TP-7@1.5m	30.47	1.70	1.30	14.98
1TP-7 @3m	28.46	1.76	1.37	15.51
TP-8 @1.5m	26.83	1.72	1.36	15.15
TP-8 @3m	24.46	1.78	1.43	15.68

The in-situ tests for moisture content, bulk density, Dry density and bulk unit weight of the study area range from 20.36 to 32.75%, 1.64 to 1.79 g/cm^3, and 1.25 to 1.43g/cm^3 and 14.45 to 15.75kN/m^3, with the average of 28.92%, 1.72 g/cm^3, 1.34 g/cm^3 and 15.17 g/cm3, respectively, are shown in Table 4.1. As the most study area, the depth of the soil layer increases, the moisture content increases of study area and the bulk density, dry density and bulk unit weight increases with increase depth. This indicates that the infiltration rate of the soil increases with increase the particle size so that the moisture content of the soil is higher when it became deeper and deeper and vice versa of study area and apparent difference between an upper and lower layer of the study area. From the laboratory results of the density show greater values than the field density results of this study.

Index Properties

Atterberg limit test, hydrometer analysis, specific gravity and free swell tests are among the tests which show the index properties of a soil. Tests were carried out on disturbed and undistributed soil samples are taken from different sites in Bellessa Town is to be performed. Eight locations of soil samples were selected based on visual observation and purposive sampling methods; soil sample are taken below 1.5 to 3m depths from the natural earth surface to avoid organic matter influence. The results of index properties of expensive soil are obtained from the experiment which conducted in the laboratory. The index properties of soils such as liquid limit, plastic limit, grain size distribution analysis such as gravel, sand, silt & clay, and specific gravity. While compaction characteristics used were maximum dry density & optimum moisture content. Results of gravel, sand, silt and clay were obtained by sieve analysis. While optimum moisture content and maximum dry density were obtained by compaction test.

Specific Gravity Test and Grain Size Analysis Results and Discussion

Determination of specific gravity is important to determine the size of the soil grains in hydrometer analysis. ASTM D 854-98 Standard Test was used; there are two methods for performing the specific gravity Method A- Procedure for Moist Specimens is preferred for organic soils; highly plastic, fine grained soil, tropical soils and soils containing halloysite. The test results specific gravities are shown in table.

This test is performed to determine the distribution of particle size of the soil in the study area using ASTM D422-standard test method. The distribution of particle sizes larger than 75µm (retained on the No.200 sieve) was determined by sieving, while the distribution of particle sizes smaller than 75µm was determined by a sedimentation process, using a hydrometer. For this test it was difficult to pulverize soil sample to individual particles Therefore, wet sieve analysis was used for all of the samples collected from the site for accurate determination of particle finer than 75µm in soil prior to dry sieving. Eight pits were selected from different locations for which the number of test pits required for a project depends on primarily on uniformity of soil samples and type of construction on the area. Disturbed samples were taken from an area where there was a huge potential of expansive soil. Standard test method and the classification of the study area were based on AASHTO soil classification system as shown in Table 3.

Table 3: Specific Gravities Test Results and Summary of Grain Size Analysis Based on ASTM

Location	Specific gravity	Gravel (%)	Sand (%)	P200 (%)	Silt (%)	Clay (%)
TP- 1@1.5m	2.75	0.46	6.80	92.74	58.64	34.10
TP-1 @3m	2.67	0.36	8.92	90.72	42.28	48.44
TP-2 @1.5m	2.74	2.44	18.10	79.46	45.18	34.28
TP-2 @3m	2.65	0.28	6.50	93.22	53.69	39.53
TP-3@1.5m	2.73	1.14	13.64	85.22	44.79	40.43
TP-3 @3m	2.63	0.14	7.36	92.50	58.34	34.16
TP-4@1.5m	2.72	0.72	30.14	69.14	45.28	23.86
TP-4 @3m	2.85	0.04	2.86	97.10	53.49	43.61
TP-5 @1.5m	2.73	0.08	14.04	85.88	55.12	30.76
TP-5 @3m	2.67	0.06	17.64	82.30	50.61	31.69
TP-6 @1.5m	2.66	0.14	7.84	92.02	54.40	37.62
TP-6@3m	2.64	0.12	5.44	94.44	57.52	36.92
TP-7 @1.5m	2.77	0.16	11.82	88.02	56.43	31.59
TP-7 @3m	2.66	0.12	7.24	92.64	57.27	35.37
TP-8@1.5m	2.67	0.36	7.44	92.20	55.48	36.72
TP-8@3m	2.76	0.18	8.16	91.66	60.30	31.36

Based on Table 3 and from grain size distribution, percentage passing sieve no 200 it is possible to classify soils with specific gravity greater than 2.65 are either silty inorganic or Clay inorganic. Accordingly, test results are shown in Table 4.2, it indicated the specific gravity of the study area were fine soil ranges from 2.63 – 2.85 it tells the absence of organic matter according to [8].

As per the grain size analysis the range of soil samples were found to be 0.04-2.44% for Gravel, 2.86-30.14% for sand, 69.14-97.10% for fine soil, 42.28-60.30% for silt and 23.86-48.44 for Clay soil with the percentage finer than 0.075 mm ranges from 69.14 to 97.10%. The results convinced that the study area is dominantly fine- grained soil so called silt and clay with the average of 0.43% gravel, 10.87% sand, 53.05% silt, and 35.65% of clay in the Balesa town according to USCS soil Classification.

Atterberg Limit Tests, Free Swelling Test Results and Shrinkage Limit

Atterberg Limits were determined on air dried samples. ASTM D 4318-98 Standard Test method for Liquid Limit, Plastic Limit, and Plasticity Index of soil were followed. Atterberg limit test was conducted in this research for the purpose of obtaining the basic index information and plasticity of the fine-grained soils used to identify the soils and to classify them. In the present study the Atterberg limit tests was presented in Table 4.

Holtz and Gibbs, (1956) suggested this method to measure the expansive potential of soil. The test results of free swell are presented in table. The amount of swelling is known to be dependent on the clay minerals, the soil mineralogy and structure, fabric and several physic-chemical aspects of the soil. To study the swelling property of the soils, the simplest test conducted is free swell test. The test is conducted by adding 10ml of dry soil passing No.40 sieve into 100ml graduate cylinder filled with distilled (tap) water. After 24 hours, final volume of the suspension being read. The free swell of the soil is then determined as a ratio of the change in volume to the initial volume.

The term shrinkage limit, expressed as water content in percent, is typically assumed to represent the amount of water required to fill the voids of a given cohesive soil at its minimum void ratio obtained by drying (usually oven). Thus, the concept shrinkage limit can be used to evaluate the shrinkage potential or possibility of development, or both, of cracks in earthworks involving cohesive soils. Data obtained from this test method may be used to compute the volumetric shrinkage and linear shrinkage. Shrinkage Limit is used also as a guide to the determination of potential expansiveness. Altmayer suggested the following relation [9].

Table 4: The Atterberg Limits, Shrinkage Limit and Free Swell of the Study

Location	LL (%)	PL (%)	PI (%)	Shrinkage limit, %	Free swelling test, %	Degree of Expansion
TP- 1@1.5m	74.53	21.35	53.18	30.00	80	Very high
TP-1 @3m	78.16	20.62	57.54	31.43	90	Very high
TP-2 @1.5m	69.16	12.31	56.85	24.29	70	Very high
TP-2 @3m	55.52	19.06	36.46	18.57	50	Very high
TP-3@1.5m	68.04	15.79	52.25	21.43	60	Very high
TP-3 @3m	53.48	13.47	40.01	18.57	50	Very high
TP-4@1.5m	67.91	12.81	55.1	25.71	75	Very high
TP-4 @3m	57.36	21.22	36.14	19.29	55	Very high
TP-5 @1.5m	63.49	13.54	49.95	27.86	78	Very high
TP-5 @3m	67.26	12.8	54.46	22.14	68	Very high
TP-6 @1.5m	73	15.94	57.06	23.57	70	Very high
TP-6@3m	70.33	20.83	49.5	21.43	60	Very high
TP-7 @1.5m	68.97	13.83	55.14	25.64	75	Very high
TP-7 @3m	66.46	14.51	51.95	27.71	76	Very high
TP-8@1.5m	58.68	15.25	43.43	20.71	58	Very high
TP-8@3m	67	12.88	54.1221	28.43	79	Very high

The results of the Atterberg's limits are presented in Table 3.3. The results of liquid limit, Plastic limit and plastic index range from 53.48 -78.16%, 17.47-26.81% & 36.01-57.54% respectively. The data indicates the of value of LL is 55 – 64% which indicates greater than 50%, high swelling potential according to, the value of PL is 32-38% and PI is 21-26%% which indicates high expansive soil according to [10, 2].

Generally, the soil under investigation consists mainly of inorganic clay of high plasticity with some fractions of silty or clayey sands. The amount of volume change exhibited by various soils under various placement conditions varies greatly.

Investigation of study area was found to be 55 – 90% for free swelling test value, Percent of swell is >50 very high degree of expansion this shows that the study areas are very high degree of expansion.

The liner Shrinkage Limit of study area was found to be 18.57 – 31.43%, Percent of liner shrinkage is greater than 12 from the test results that all of test pits are found in the non-critical expansion potential and that soil exists in this area was found in very expansive according to [9].

Classification of Soil

In this thesis work, classification was made based on the two most popular engineering soil classifications namely: Unified Soil Classification System (USCS), and AASHTO classification system.

Unified Soil Classification System

The Unified Soil Classification System (USCS) was first developed by Casagrande in 1948. The system is the most popular system for use in all types of engineering problems involving soils. Experimental results from soils tested from different samples were plotted on a graph of plasticity index (ordinate) versus liquid limit (abscissa) as shown in fig. 4.3 while classified results, according to UCSCS, were obtained from PL, LL and PI as shown in table 4.4 Fine grained soil based on percentage of the soil passing No. 200 sieve. From the result sieve analysis, the 50% of the sample soil passes No. 200 sieve therefore fine-grained soils. Fine grained soils are further divided into two types. Soils of low plasticity (L) if the liquid limit is 50% or less, Soils of high plasticity (H) if the liquid limit is more than 50%. As shown in the figure 4.2 plasticity chart of the soil, the A- line has the equation Ip = 0.73(wl-20) separates the clays from silts. In the same plot of the chart, the soils around the area are classified as CH which is Inorganic clays of high plasticity.

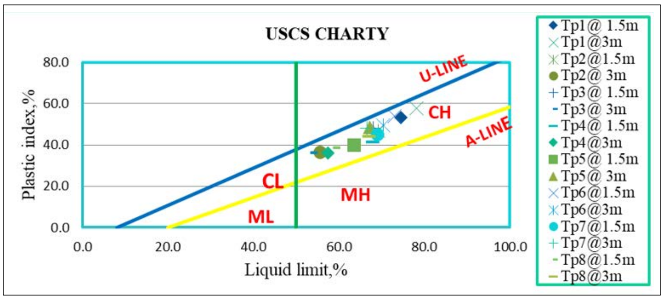

Figure 2: USCS Plasticity Chart

According to USCS as shown in figure 2 all of study area were lie below A-Line. Therefore, the soils of the study area fell under CH region which shows that the soil are fine grain soil which indicated that Clay of high plasticity (CH) according to USCS soil classification.

AASHTO Classification System

The American Association of State Highway and Transportation Official (AASHTO) Classification system is useful for classifying soils for highways. The particle size analysis and the plasticity characteristics are required to classify a soil. The classification system classifies both coarse grained and fine-grained soils. The AASHTO system uses similar techniques but the dividing line has an equation of the form PI=LL-30. It generally classifies a soil broadly into granular material and silt clay material. The granular material is further divided into three groups which are A-1, A-2 and A-3. The silt clay material is in turn divided into four groups A-4, A-5, A-6 and A-7. Soils of the study area are classified after conducting index tests such as liquid limit (LL), plastic limit (PL) and grain size analysis. Since the percentage of particles passing 0.075 mm sieve for all soil sample is greater than 35%, soils of the study area are found to be fine grained soil, as shown in the figure 3.

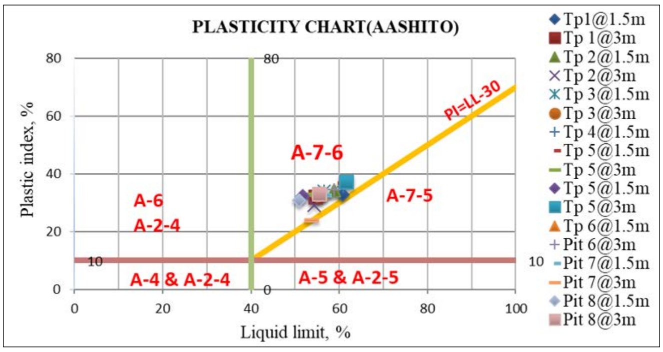

Figure 3: (AASHTO) Classification System

Most of the soils of the study area fell under A-7-6, as shown in figures 3.2, which indicate that the soils are clay according to the AASHTO classification. A-7 materials are commonly considered the poorest performers of soil with regard to roadway construction. Further, more group index values of the samples were calculated and indicated that all of soil samples are more than 20 which indicates that percentage number of fine particles 75µm is high, hence, the soils are highly plastic nature and cannot be used for subgrade material.

Activity (Colloidal Activity)

Skempton's colloidal activity is determined as the ratio of the plasticity index to the clay content in the fines. This method is developed by combining Atterberg limits and clay content into a single parameter called Activity. These values are presented in the form of chart, which is called Activity Chart, and the soil of the study area is compared to the values and it falls in the range of Active clay.

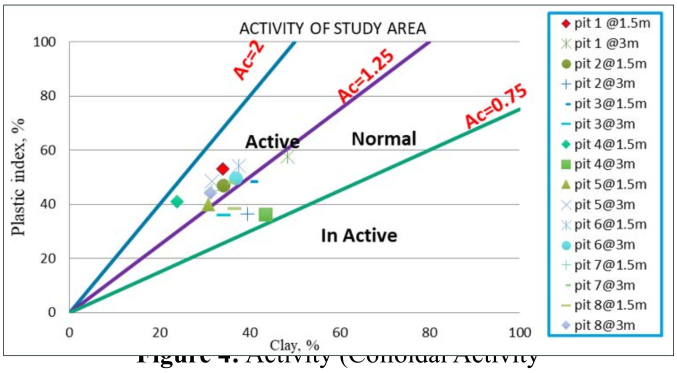

Figure 4: Activity (Colloidal Activity)

From the results under Figure 3.3, it can be seen that the activity of the study area ranged from 0.83 to 1.72, Activity of study area were greater than 0.75. Most of soil fall under Active which signifies that the soils of the study area were expansive soil.

Engineering Properties

Compaction Characteristics, Permeability and Unconfined compression Test

The compaction test has been conducted to obtain maximum dry density and optimum moisture content of expansive soil. The concept used in test explains that any comp active effort i.e.; MDD depends upon the OMC in soil. The below data table is obtained from test conducted which helps in plotting the graph i.e.; OMC in x-axis and MDD in y-axis.

Permeability of a soil is the rate at which water flows through it under action of hydraulic gradient. The passage of moisture through the inter-spaces or pores of the soil is called 'percolation'. Soils having porous enough for percolation to occur are termed 'pervious' or 'permeable', while those which do not permit the passage of water are termed 'impervious' or 'impermeable due to the results all the area was impermeable

The objective of the Unconfined compression test is to determine the UU (unconsolidated, undrained) strength of a cohesive soil. The unconfined compression strength test was conducted on undisturbed samples of Balesa area using ASTM D 2166.

Table 5: Compaction Test Results, Permeability Test and Unconfined Compression Test Result

Location	OMC (%)	MDD (g/cm^3)	Coefficient of permeability	Unconfined Compressive Strength, kPa	Consistency
TP- 1@1.5m	32.03	1.45	(k) (cm/sec)	79.26	Stiff
TP-1 @3m	39.79	1.33	1.10712E-07	109.18	Very stiff
TP-2 @1.5m	29.98	1.46	1.21447E-07	96.79	Stiff
TP-2 @3m	35.32	1.35	1.19494E-07	158.08	Very stiff
TP-3@1.5m	27.06	1.48	1.48581E-07	150.48	Very stiff
TP-3 @3m	29.84	1.49	9.28275E-08	138.82	Very stiff
TP-4@1.5m	37.15	1.36	5.36543E-08	66.70	Stiff
TP-4 @3m	31.43	1.29	7.26247E-08	83.33	Stiff
TP-5 @1.5m	1.29	33.70	1.3248E-07	68.13	Stiff
TP-5 @3m	1.33	1.33	2.41094E-08	55.98	Stiff
TP-6 @1.5m	31.82	1.34	7.78282E-08	85.98	Stiff
TP-6@3m	31.25	1.38	1.20193E-08	116.16	Very stiff
TP-7 @1.5m	30.7	1.48	2.00538E-07	78.44	Stiff
TP-7 @3m	30.25	1.41	2.20721E-07	64.02	Stiff
TP-8@1.5m	37.5	1.35	7.13724E-07	117.31	Very stiff
TP-8 @3m	34.9	1.37	3.4414E-08	109.80	Very stiff

The test results show that the MMD ranges from 1.29 to1.61 g/cm3 and the OMC ranges from 20 to 40 %, most of study area was fine grain soil. Compaction test results are summarized in Table 5.

The investigation of study area found to be 1.20193E-08 to 7.13724E-07 for coefficient of permeability, relatively impervious and have low permeability coefficient which indicated that soil sample was fine soil or clay according to the [11].

The results show that the soils are in stiff to very stiff consistency range from 55.98-158.08 kN /m2 therefore, the most soil samples of study area was stiff clay.

Results from the Consolidation Test

Based on previously retrieved undisturbed samples from the study area, consolidation tests were conducted in accordance with ASTM D2435, and detailed calculations are presented in Appendix G and the consolidation parameters of selected samples are presented in Table 4.13 consolidation tests result of some pits.

Table 6: Consolidation Test Result

Location	Compression Index (Cc)	recompression Index(Cr)	Swelling Potential (%)	swelling pressure (kPa)
TP- 1@1.5m	0.385	0.092	0.94	13
TP-1 @3m	0.085	0.017	7.54	18
TP-2 @1.5m	0.13	0.01	0.29	15
TP-2 @3m	0.07	0.03	1.72	70
TP-3@1.5m	0.045	0.008	0.08	7
TP-3 @3m	0.04	0.007	0.29	18.5
TP-4@1.5m	0.071	0.021	4.34	40
TP- 4@3m	0.038	0.006	0.28	19.5
TP- 5@1.5m	0.083	0.016	7.53	184
TP-5 @3m	0.068	0.029	1.71	71
TP-6@1.5m	0.043	0.007	0.07	8
TP-6@3m	0.128	0.009	0.28	16
TP-7@1.5m	0.069	0.02	4.3	41
TP-7@3m	0.383	0.091	0.93	14
TP-8@1.5m	0.067	0.026	1.68	54
TP- 8@3m	0.126	0.019	0.34	19

The results were found to be 0.07-754% for swelling potential, 7-184kPa for swelling pressure 0.038-0.385 for compression index and 0.006-0.092 for recompression index. Therefore, the most study area of soils samples have shown fine grained soils.

The Effect of Wooden Ashes on Atterberg Limit Test

The liquid limit and the plastic limit tests for original soil and soil with additives (Wooden ashes) was carried out according to the ASTM D-4318. Atterberg limit test was conducted in this research for the purpose of obtaining the basic index information and plasticity of the fine- grained soils used to identify the soils and to classify them. In the present study the Atterberg limit tests follow ASTM D 4318 procedure. In this research the soil was dry mixed with the additives (Wooden ashes) and allowed to mellow prior to initiating the test. The percentages of additive were (0, 2.5, 5, 7.5, 10 & 15) % from the weight of soil. Table 3.6 shows soil-additives mix, liquid limit test and plastic limit test respectively at different percentages.

Table 7: The Effect of Wooden Ashes on Atterberg Limit Test

S/No	Description	LL (%)	PL (%)	PI (%)
1	Expansive soil alone	63.49	13.54	49.95
2	Expansive soil + 2.5% of wooden ashes	55.3	12.82	42.48
3	Expansive soil + 5% of wooden ashes	44.5	11.46	33.04
4	Expansive soil + 7.5% of wooden ashes	47.1	10.31	36.79
5	Expansive soil + 10% of wooden ashes	40.4	9.68	30.72
6	Expansive soil + 15% of wooden ashes	46.3	11.81	34.49

Liquid limit, Plastic limit and Plasticity index for the soil samples modified with a different percent of wooden ashes presences. As can be seen from the Table 3.6, the increase in wooden ashes contents has significant impact on Liquid limit, Plastic limit and Plasticity index when wooden ashes added by weight on expansive. Increase Wooden ashes decrease Liquid limit, Plastic limit and Plasticity index of soil until it reaches peak point then increasing value of Liquid limit, Plastic limit and Plasticity index of expansive soil. Moreover 10% of wooden ashes lead to the smallest value Liquid limit, Plastic limit and Plasticity index were obtained. The contribution of wooden ashes to the Liquid limit, Plastic limit and Plasticity index decreases with increasing ashes contents. By various % of wooden ashes is blended with expansive soil; it is indicated that highest (optimum value) of Plasticity index values were obtained at 10% of wooden ashes therefore, increasing shear strength of expansive soil with increasing wooden ashes content.

Effect of Wooden Ashes on Compaction Parameters

The variation of compaction parameters (maximum dry density and optimum water content) of the treated soil samples are graphically plotted in Figures 4.9. It is clearly observed that the treatment of soil samples by wooden ashes has significant effect to the soil strength, the maximum dry density and the optimum water content increased with increasing wooden ashes. However, the presence of wooden ashes was greatly improved the soil strength. The compaction test has been conducted to get connection between wooden ashes and dampness substance of soil in order to obtain maximum dry density and optimum moisture content of expansive subgrade soil. The concept used in test explains that any comp active effort i.e.; MDD depends upon the OMC in soil. The below data table is obtained from test conducted which helps in plotting the graph i.e.; OMC in x-axis and MDD in y-axis.

Table 8: Summary of Effect of Wooden Ashes Compaction Properties of Soil for TP-5

S/No	Description	MDD (g/cm^3)	OMC (%)
1	Expansive soil alone	1.29	33.70
2	Expansive soil + 2.5% of wooden ashes	1.32	34.80
3	Expansive soil + 5% of wooden ashes	1.34	35.00
4	Expansive soil + 7.5% of wooden ashes	1.38	36.84
5	Expansive soil + 10% of wooden ashes	1.51	40.65
6	Expansive soil + 15% of wooden ashes	1.40	38.10

The compaction characteristics for samples with different wooden ashes percentages, it is observed from this table that for a given wooden ash, increasing the percentage of wooden ashes results in increase in maximum dry unit weight and optimum water content. For the percentage wooden ashes of 2.5%, 5%, 7.5%, 10% & 15% wooden ashes adding are that shows an increasing. It can be said that by increasing them percent of wooden ashes in the sample is increased and the contact between soil particles and wooden ashes is increased which results in increase in the strength.

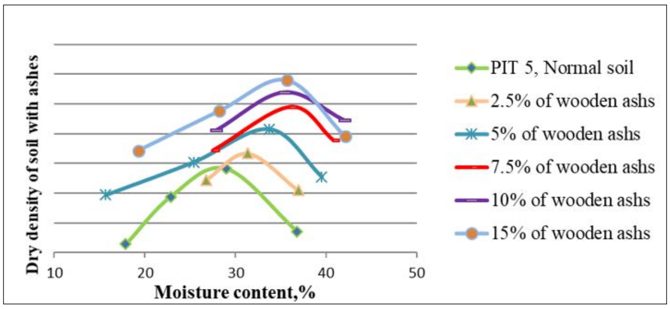

Figure 5: Effect of Additives on Compaction Parameters for Tp-5

Generally, as you have seen from the above figures increase ashes increase maximum dry density and optimum moisture content of soil until it reaches peak point then decreasing value of maximum dry density and optimum moisture content of expansive soil. Moreover 10% of wooden ashes lead to the largest value MDD & OMC were obtained. The contribution of ashes to the compaction characteristics (i.e., maximum dry density) increases with increasing ashes contents.

Effect of Wooden Ashes on Unconfined Compression Strength of Soil

The unconfined compressive strengths of the study area sample soil performed in the laboratory result with variation percentage of wooden ashes in order to obtain optimum value of shear strength of expansive soil as outlined in the finding of laboratory result of this thesis. The amount of strength increases in a clay soil that can be produced by adding wooden ashes.

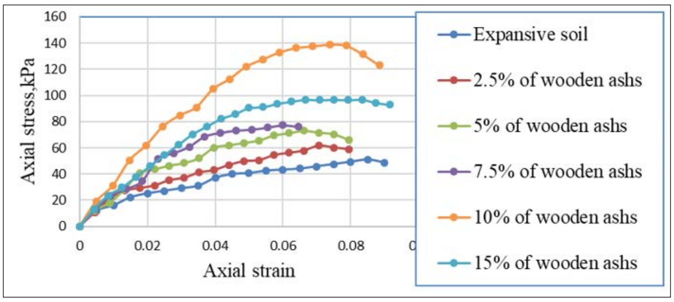

Figure 6: Effect of Wooden Ashes Stress-Strain Curves on Unconfined Compressive Strength for TP-5

Table 9: Unconfined Compression Strength of Soil with Wooden Ashes for TP-5

S/No	Description	Qu (kPa)	Cu (kPa)
1	Expansive soil alone	50.94	25.47
2	Expansive soil + 2.5% of wooden ashes	61.57	30.78
3	Expansive soil + 5% of wooden ashes	72.97	36.49
4	Expansive soil + 7.5% of wooden ashes	77.20	38.60
5	Expansive soil + 10% of wooden ashes	138.82	69.41
6	Expansive soil + 15% of wooden ashes	96.95	48.47

When the effect of wooden ashes increasing the contents of additives varying in their percentage which mixed with expensive soil; it is indicated that highest (optimum value) of unconfined compressive strength values of the strengthen soil were obtained at 10% of wooden ashes, therefore, increasing shear strength of expansive soil, with increasing wooden ashes content. The effect of wooden ashes content on the strength is marked, the higher wooden ashes content the greater the strength, which helps in increasing bearing capacity and soil shear strength of expansive soil.

Influence of Wooden Ashes on Swelling Properties of Expansive Soil

The swelling pressure decreased significantly with increasing wooden ashes content. The maximum Swelling potential and swelling pressure for the control clayey soil was observed to be; however, the minimum swelling pressure was found when the clayey were mixed to 10% wooden ashes content.

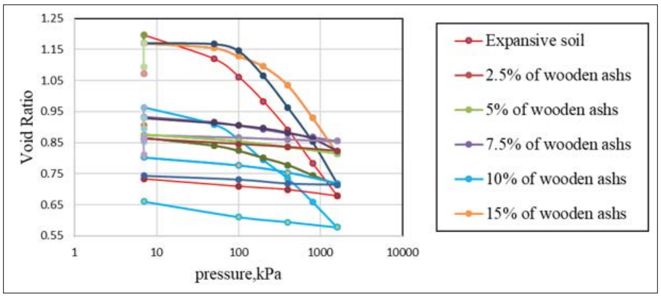

Figure 7: The Effect of Wooden Ashes on Consolidation Test

Table 10: The Effect of Wooden Ashes on Consolidation Test

S/No	Description	SP (%)	SP(kPa)	Cc	Cr
1	Expansive soil alone	4.8	190.6	0.0313	0.0023
2	Expansive soil + 2.5% of wooden ashes	4.7	152.9	0.0305	0.0015
3	Expansive soil + 5% of wooden ashes	4.4	144.4	0.0315	0.0025
4	Expansive soil + 7.5% of wooden ashes	4.8	172.6	0.0309	0.0019
5	Expansive soil + 10% of wooden ashes	4.6	156.1	0.0314	0.0024
6	Expansive soil + 15% of wooden ashes	3.6	137.8	0.0302	0.0012

Table 10 and Figure 7: shows, the coefficient of compression, coefficient of recompression, swelling potential and the swelling pressure for the soil samples modified with a different percent of wooden ashes. As can be seen from the Table 3.9, the increase in wooden ashes contents has significant impact on both swelling potential and the swelling pressure when wooden ashes added by weight on expansive. Increase wooden ashes decrease the coefficient of compression, coefficient of recompression, swelling potential and the swelling pressure of soil until it reaches peak point then increasing value of the coefficient of compression, coefficient of recompression, swelling potential and the swelling pressure of expansive soil. Moreover 10% of wooden ashes lead to the smallest value the coefficient of compression, coefficient of recompression, swelling potential and the swelling pressure were obtained, expansive soil + wooden ashes compacted together which gives optimum value were obtained at 10% of wooden ashes. The contribution of fiber to the coefficient of compression, coefficient of recompression, swelling potential and the swelling pressure decrease with increasing ashes contents [12-37].

Conclusions

- The total sample observed was eight and it belonged to fine-grained soils. From the above study the following conclusions can be made in Ballesa Town:
- The study was made to assessment of expansive properties of soils and remedial measure with wooden Ashe in order to provide soil information for safe and cost-effective design of civil structures.
- The test results showed that the study area was found to be A-7-6 soil as per AASHTO soil classification system; with high liquid limits. Moreover, as per USCS soil classification system all of the soils are grouped as CH (inorganic Clay with high plasticity).
- The laboratory test result for this study was given the following: The soils have liquid limit ranging from53.48 to 78.16%, plastic index ranges from 36.14 to 57.54% and specific gravity ranging from 2.62 to 2.85. The free swell of soils ranging from 50 to 90%, but most of the soil on the study area have the free swell of greater than 50% indicates that the soils high expansive.
- The activity of the soils greater from 0.83 which is indicates the soils are active. Therefore, from this study conclusion can be made there were high considerable problematic soil distribution of soil.

- The results obtained from grain size analysis the clay content ranges from 20.74to 42.04%, silt ranges from 40.14 to 65.89%, sand ranges from 2.29to 30.6% and gravel ranges from 0 to 14.1%. The clay soils have consistency of stiff to very stiff, have unconfined compressive strength of 55.7 to 158.1kN/mm2 with natural moisture content of from 22.80 to 32.75%.
- The results of compaction test show maximum dry density ranges from 1.29 to 1.49gm/cm3 and optimum moisture content ranges from 26.13 to 39.79%. The clay soil has compression index (Cc) values ranges from 0.13 to 0.35 and recompression index values ranges from 0.008 to 0.092. The coefficient of permeability (K) ranging from 1.20193* 10-8 to 7.13724*10-7(cm/sec). This result shows the soil has poor drainage condition for subgrade.
- Increasing wooden ashes decreasing the coefficient of compression, coefficient of recompression, swelling potential and the Swelling pressure of soil until it reaches peak point then increasing value of the coefficient of compression, coefficient of recompression, Swelling potential and the Swelling pressure of expansive soil.
- Expansive soil + wooden ashes compacted together which gives optimum value were obtained at 10% of wooden ashes. The contribution of wooden ashes to the coefficient of compression, coefficient of recompression, swelling potential and the Swelling pressure decrease with increasing ashes contents
- The percentage of wooden ashes increase it shows increase in dry density. Liquid limit, plastic limit, & plastic of soil decrease with increasing wooden ashes contents, swelling potential of soil decrease with increasing percentage of wooden ashes.
- The percent of wooden ashes increase compaction characterization of soil increase and compressive strength of soil is also increased with increasing the percentage of wooden ashes content.

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