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An Experimental Study on Soil Stabilization by Using Cement and Incinerated Bottom Ash

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ABSTRACT- This main objective of this study is to improve the strength of peat soil by adding industrial waste as a filler and cement as a binder. Peat soil are known to have a weak strength and a very high settlement problem. However, past researches have shown that the strength of peat could be improved by using soil stabilization method. In this study, the peat stabilization project includes using bottom ash as the industrial waste which acts as a filler, Portland-limestone cement (PLC) as the binder and the implementation of Bottom Ash as an additive along with the process control agent (PCA) and without process control agent (WPCA). The compressive strength (CS) test are conducted to further study the effect of bottom ash in the strength of stabilized peat. The physical properties of the soil are also studied which includes the density, moisture content, porosity, specific gravity and shrinkage. In order to compare the results, different variation of samples with bottom ash & sand along with PLC are also used to distinguish the roles of different fillers and chemical additive. The comparison will further indicate whether the combination of bottom ash and PLC are suitable for the study of peat stabilization. The proportion for the mix design will be 5 parts of filler (bottom ash/sand), 3 parts of PLC, 5 parts of peat. The samples were casted in the 100 * 100* 100 mm moulds and then were opened after 30 days. The experiments are carried out after the samples have been air cured for 28 days. The compressive strength of the stabilized peat with bottom ash and PLC produces the strength at 3.6 MPa compared to the other samples while as from the previous researches, Peat with sand & PLC having a compressive strength of 0.79MPa. The result shows that the combination of bottom ash as the filler can be used to further improve the strength of peat stabilization.

KEYWORDS- Bottom Ash, Compressive Strength, Marshy Soil, Strength, Stabilization.

I. INTRODUCTION

Peat is a brown-black colored soil and produced from decomposed organic matter under the presence of water and oxygen-insufficiency conditions. Peat soil is one of the important aspects in the ecosystem which provides a significant contribution to the global climate stability. Peat soil covers about thirty million hectares of land in the total world coverage with Canada and Russia as the largest distribution of peat. Based on the previous solutions conducted to cater the problem with construction on peat soil, the main solutions are classified into several ways, which are land removal, soil stabilization and piling. In land removal, the soils with lower strength such as peat will be removed from the site and replaced with a stronger type of soil. However, this solution could not be effective for peat with depth of more than 3 m as the excavation of soil will cause disturbance in soil properties and it requires higher expenses. Generally, the engineers will be induced into proposing soil stabilization as the solution for this problem. The soil will be mixed with certain additives, chemicals or cement in order to create a more solid layer of soil. This solution has been proven to be effective as it shows significant difference in terms of strength and settlement. A study that has been conducted by Sadek, Roslan and Abubakar[15] shows that the peat soil that has been mixed with cement, additives (bentonite) and sand have improved the engineering properties of the soil by increasing the bearing capacity, increase in maximum dry density and decrease in soil liquid limit and moisture content."

This Bottom ash, a Coal Combustion Product (CCP) is composed of clustered ash particles in nature which are usually coarser than fly ash particles. It is the slag which is formed on the heat absorbing surfaces of the furnace, and which subsequently falls down to the furnace bottom. It is typically grey to black in color and is quite angular and has a porous sur face structure. According to Central Electricity Authority annual Report [2011-12] total bottom ash generated in India annually is about 15 to 20 million tonnes. It poses a great threat to environment if not taken care of properly. This can result in the pollution air, water and soil and it is also harmful to humans and other living organisms. Studies have shown that bottom ash can be used in pavement construction as filler, as a replacement of binder material, as an embankment material and as a replacement of natural aggregate. Use of bottom ash in road construction can result in reducing cost of construction as well as protects environment and conserves natural resources. Usage of Bottom Ash in construction practices is a part of Solid Waste Management. In highly populous countries like India where most of the areas are densely populated, it is not easy to find a suitable site for dumping waste materials. Even if found, doing the same will pose great threat to natural resources like air, water and soil as well as to living organisms nearby."

Studies have shown that using bottom ash as a replacement of fine aggregate in concrete mixes, it is has improved the overall performance along with properties like compressive strength, durability etc. In cases where bottom ash was used as a replacement of filler in bituminous mixes it has been found that modified mix was having improved values of rutting factor and dynamic viscosity compared to the normal mix. Various studies have been done upon utilization of bottom ash in various sections of road construction and almost all results validated beneficial outcomes.

A. Significance & Scope of Study

The main study for this experiment is to stabilize peat soil using bottom ash to create a more solid layer of soil. Bottom ash which is the industrial waste of the burning of fossil fuels has been proven to improve the strength of soil structure.

The bottom ash has been used as a fill material in road construction in Sweden. The bottom ash was used as a subbase material and it has been showing positive results as bottom ash reduces the cost of road construction and decreases the need of ground improvements. Bottom ash has also been used as a light fill material for soil layers of soft clay with lower compression modulus and weaker shear strength and soil stability was achieved.

Civil engineers often encounter several problems with peat soil in construction aspect, as peat has a lower settlement rate and has low compressive strength. For a 3m deep peat, the need to extract the peat and replace with other soil will require more budget and it might disturb the properties of the soil. One of the better and cheaper way to counter this issue is to implement soil stabilization. Thus, industrial waste (bottom ash) will be introduced in this study in order to create a stronger layer of peat and increase the settlement rate as well as its compressive strength. The expected outcome of this study would be useful for engineers to solve the existing problem associated with peat soil. Furthermore, it could also be beneficial to the environment as the impact of disposal of industrial wastes could be significantly reduced as it is being implemented in peat stabilization."

The main purpose of this study will be focusing more on the effect of industrial waste as a filler and the addition of chemical additives in stabilizing the peat soil by increasing its compressive strength. Peat soil that will be used in this study is taken from Pulwama, Srinagar and Ganderbal, and the tests will be conducted in a laboratory condition. The physical properties that will be measured includes density test, specific gravity, moisture content, porosity and shrinkage. Meanwhile, the mechanical properties of the stabilized soil are determined by conducting Compressive Strength test (CS).

B. General Properties of Peat

Sadek, Roslan and Abubakar [16], stated that numerous drainage and irrigation schemes in the peat land area were subsequently implemented and proposed. These schemes are planted with cocoa, paddy and other mixed crops. Nonetheless, most of these systems are still underused. These schemes should be analyzed in order to ensure optimum use. Also, peat soil has distinguished properties which differs it from mineral soils and it requires certain consideration. The characteristics of peat includes high moisture content, high compressibility, low shear strength, dark brown/black in color and has a spongy-like properties. Peat soil also have small surface of soil particles which is less than 40% of the soil itself and the other 60% is organic matter. Peat soils have very low pH value ranging between 3.5 to 4.0 and it has high level of acidity. Peat can be considered as a very light structure because of the low percentage of soil particles. This have caused plantation to tumble over as the roots have nothing to hold on to. In order to continue with plantation, the peat soil should be compacted to make it denser using roller machineries. Peat soil contains high organic content (> 75%) which consist of plant that accumulate faster than the rate of decay[1]. Different locations of peat soil across the country have different content as it is affected by the difference in temperature and the level of humification. The benefits of peat soil can be illustrated in the Table 2.2.

Abdel-Salam [14], stated that the classification of peat and organic soil can be determined according to the degree of humification (decomposition) which is divided into 10 levels, having H1 being the lowest and H10 being the most decomposed.

Murtedza et al., [15], stated that there are two subgroups of organic soil based on its surface vegetation which are the montane forest (highland organic soil) and peat swamp forest (lowland). According to the two subgroups, it can be differentiated according to the family and series depending on the organic materials, groundwater table, ash content and nature of mineral substratum.

Based on the study that has been conducted by Kifli et. al. [17], peat contains high amount of organic matter as it accumulated throughout the last 20,000 years. The amount of organic matter may differ for different locations depending on the climate, local vegetation and soil type. Kifli et al. [17] conducted a study on the compositions of peat soil, which consist of the moisture content, ash content, organic content, specific gravity, fiber content and pH value.II**.**

II. EXPERIMENTAL PROCEDURE

A. Materials

They are several ways that can be apply or implement in order to improve peat problems in relation with the strength and stability of the peat by producing solid strong layer of stabilize soil. The materials that can be used in stabilizing peat soils are by using Portland Limestone Cement (PLC) as a binder, PCA as the chemical additive and industrial waste such as bottom ash as an additive.

1) Portland Limestone Cement (PLC)

Tsivilis et. al. [12] shows the cement is a material that is widely used in construction industry. Portland-limestone Cement (PLC) are considered as one of the cements that can be used as a binder other than Ordinary Portland Cement (OPC). PLC is a type of material which hardens and binds other materials when there is presence of water. PLC can be used to stabilize soil to make it strongerand more solid since it is easy to handle and easy to control. As the amount of cement increase in soil stabilization, the strength of stabilized soil also increases[2]. Several studies that have been conducted stated that cement is suitable for soil stabilization of granular and clay soil which have low plasticity index. In this case, cement is an ideal material to be used as a soil stabilizer for peat soil as it has similar properties with clay soil.The difference between PLC and other pure cements is that PLC requires less water in orderto react due to the finer particle size of PLC. The higher content of limestone in PLC decreases the water demand which can contribute to the different particle size distributions in a sample.

2) Sand

Sand can be defined as a mixture of smaller particles of rocks and granular materials. According to Alam, sand is said to have a smaller size than gravel but relatively coarser than silt with a ranging size of 0.06mm to 2mm. Sand can be formed from small broken pieces of coral, shell, and other minerals discarded by the sea and aquatic animals in the ocean. Furthermore, sand consist of unconsolidated granular materials which are mainly made of silicate minerals and rocks [Siddiquee]. The minerals contain in sand is typically quartz which has a trait that is resistant to weather. Other than that, other minerals such as micas are also found in sand as well as heavy minerals like tourmaline and zircon. Moreover, most sands that are present in the beach consist of felspar and quartz.

According to ASTM, the classification of sand based on its size can be categorized into three categories which are fine sand, moderately coarse sand and coarse sand. The fine sand passes through No. 16 sieve which are commonly used for the purpose of plastering. Moderately coarse sand should pass through sieve size no. 8 which are usually used for masonry and mortar. Meanwhile, the coarse sand are the particles that passes through sieve no. 4. Coarse sand are mainly used as a small aggregate in concrete work[3].

A study was done by Celik and Canakci in [13] about the effect of sand on the properties of peat soil. The study focuses on the compaction test, shear strength and the compressibility of the peat added with sand.

III. RESEARCH METHODOLY

This study is experimental research that emphasized on laboratory test. This chapter describes the materials used and the test methods followed in performing several experimental investigations. The concept to carry out the experiment and laboratory testing are also presented and discussed in this chapter. Besides, the experimental programme can be classified into two main phases which are laboratory experiment and also the pilot of Pulwama, Srinagar and Ganderbal. The main purpose of this project is to investigate role of bottom ash in stabilizing peat soil in Kashmir in which bottom ash as industrial waste is used as additive and also Portland Limestone Cement (PLC) as the binder. The properties of peat in this project can be determined in accordance with the physical and mechanical properties. There are two types of physical properties of peat samples are determined in this study which are shrinkage limit and also specific gravity. Meanwhile, the mechanical properties of peat samples are established by conducting two main tests which are compressive strength test and micro structural analysis by using scanning electron microscopy (SEM) method.

This chapter explains the experiments conducted on the specimens and the materials used in this study. The peat stabilization project involves mixing peat soil with cement, industrial waste and chemical additives. There are four sets of samples that is tested throughout this project which is the peat soil itself, Portland-limestone cement as the binder, bottom ash and sand as the filler and process control agent (PCA) as the chemical additive. The testing involved in this project is to compare between the properties that the sample will give out as it is mixed with different fillers and chemical additives[4]. For this study, the main concern is to distinguish the effect of introducing bottom ash and sand onto the soil sample while treated with process control agent (PCA).

In order to identify the difference in their properties, the soil sample with the addition of industrial waste (bottom ash) will be compared to a control sample which is mixed with sand. The ratio of materials used for the mixing is 5 parts of peat soil, 3 parts of Portland- limestone cement, 5 parts of bottom ash and 1 part of Process control agent (PCA). Another control sample with peat, sand, PLC and Process control agent (PCA) are also used to distinguish the effect of bottom ash. The testing involved will be discussing on the physical and the mechanical properties of the soil. The physical properties test includes the density, specific gravity, moisture content, porosity and shrinkage while the mechanical properties test includes the compressive strength test (CS). All the experiments were conducted through Albani Engineering and research Group at the Geotechnical Engineering Laboratory, National Institute of Technology. The compressive strength test was conducted at Institute of Technology, Zakura, Srinagar. A flowchart that shows the workflow of this study can be shown in Figure1:

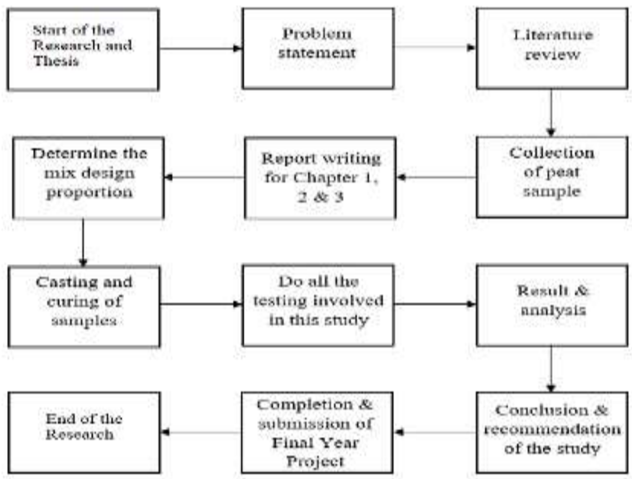

Figure 1: Flowchart of the study

IV. COLLECTION OF DATA

This research will collect data from different organizations.

- The peat soil sample was collected from Anchar, Soura by the permission of UT government.
- Geotechnical data has been collected from R&B department.
- Incinerated bottom ash has been collected from R G Contractors & Engineers, Srinagar.

A. Peat Soil

H8 sapric peat soil was cleaned thoroughly from any wood, roots and debris which might affect the mixture of soil sample shown in figure 2. The soil sample was stored in the NIT laboratory. In this study, 5 parts of dry sapric peat soil from the total weight of the sample mix will be used[5].

Figure 2: Peat soil

B. Cement

Cement is used as a binder for this project of soil stabilization. In this study, Portland- Limestone Cement (PLC) is used as a binder which was available in National Institute of Technology Srinagar. PLC has been approved as a part of the ASTM C595/AASHTO M240 specifications back in 2013 shown in figure 3. The ratio of cement in this mix is 3 parts of the total weight.

Figure 3: Portland-limestone cement

C. Bottom Ash

For this experiment, bottom ash is being used as the main material to be mixed with peat soil in order to stabilize it. Bottom ash is a coarse, granular, incombustible by-product of coal combustion that is collected from the bottom of furnaces in figure 4. The testing involved is to study the effect of bottom ash on the strength of stabilized peat soil. 5 parts of bottom ash is being used to mix with the peat soil[6].

Figure 4: Bottom ash

D. Mix Design

In this project, the design mixture consists of different materials for each variation of samples. There are four sets of mix design which will be used to compare the effect of different fillers and chemical additive. The soil sample that uses sand as a filler will be used as a control sample to get the benchmark reading for sample with bottom ash. The control sample will be a combination of peat soil, sand as a filler, Portland-limestone cement as a binder and process control agent (PCA) as the chemical additive. Each set of mix design will have samples that are molded into (100×100×100) mm of steel cube. The inner surface of the steel cube will be lightly coated with grease for easier removal of sample in the future.

For the control sample, it consists of 5 parts of peat, 3 parts of PLC, 5 parts of sand and 1 part of PCA from the total weight of the mixture. The amount water that is used for this control sample is 3.5 L for dilution and workability[7]. For the actual sample, the mixture contains 5 parts of peat, 3 parts of PLC, 5 parts of bottom ash. The total amount of water used is 3.5 L shown in Table 1 and Table 2. The mix proportion of soil sample can be shown in the following tables below."

Table 1: Mix proportion for sand sample

Proportion	Peat (by parts)	Portland - limestone cement (PLC) (by parts)	Sand	Volume of water (liters, L)
Sample 1 - 10	5	3	5	3.5

Table 2: Mix proportion for bottom ash sample

Proportion	Peat (by parts)	Portland-limestone cement (PLC) (by parts)	Bottom ash + SAND (by parts)	Volume of water (liters, L)
Sample 1 - 10	5	3	5	3.5

V. TESTS

A. Physical Test

Several laboratory tests are carried out to further investigate the physical properties of the stabilized peat. The result will then be compared with the testing than has been carried out on the control sample. The physical tests that are involved in this project are as follow:

- Density test
- Specific gravity
- Moisture content
- Porosity test
- Shrinkage percentage

B. Density Test

Density of an object are defined as the total mass divided by its total volume. Density test will be carried out by measuring the dimension of the soil sample and its mass after air cured for 28 days. The reading for each side of the dimension will be taken three times to get the average reading[8]. The weight of the sample is measured using an electronic balance.

C. Specific Gravity

The specific gravity of a substance can be defined as the density of the object divided by the density of water. By knowing the density of the sample, the specific gravity can be simply calculated by dividing it with the density of water. The specific gravity of the samples for this project are calculated using the following formula.

$$G = \frac{Density\ of\ water\ at\ 27^{\circ}C}{Weight\ of\ soil\ of\ equal\ volume}$$

$$G = \frac{(M_2 - M_1)}{(M_4 - M_1) - (M_3 - M_2)}$$

Where,

- G is Specific Gravity
- M_1 is mass of density bottle in gram
- M_2 is mass of bottle and dry soil in gram
- M_3 is mass of bottle, soil and liquid in gram
- M_3 is mass of bottle when full of liquid only in gram

D. Moisture Content

Moisture content can be defined as the mass of water present in the soil, measured by knowing the percentage difference between the moist soil and dried soil in an oven shown in figure 5. This test will be carried out by placing the soil sample in oven. The weight of the sample will be taken for every 24-hour interval until the weight of the sample becomes constant. This test was carried out by following the standard ASTM D2974-87 standard test methods for moisture, ash and organic matter of peat and other organic soils. Based on this standard, Method A will be used to identify moisture content where the soil sample will be oven dried[9]. The moisture content can be expressed from Eq.

$$w = \frac{(W_2 - W_3)}{(W_3 - W_1)} \times 100$$

Where,

- w is Water Content Percent
- W_1 is mass of container (bowl) in gram
- W_2 is mass of container (bowl) with wet soil in gram
- W_3 is mass of container (bowl) with dry soil in gram

$$w = \frac{(W_2 - W_3)}{(W_3 - W_1)} \times 100$$

Where,

- w is Water Content Percent
- W_1 is mass of container (bowl) in gram
- W_2 is mass of container (bowl) with wet soil in gram
- W_3 is mass of container (bowl) with dry soil in gram

Figure 5: Soil sample placed in the oven

E. Porosity Test

The porosity of the soil can be defined as the amount of water absorbed into the soil and fill the voids in the sample. A higher water absorption percentage of the sample indicates that the sample has a greater amount of porosity. For this porosity test, metal rods are placed and arranged at the bottom of the basin and the sample will be placed on top of the metal rod as shown in the figure below. Then, water is filled in the basin until it reaches at a height of 10 to 20mm above the metal rod. This is to allow only one side of the soil sample to be exposed to water and therefore the porosity of the soil sample can be studied as the water seeps through into the sample in Figure 6. The weight of the specimen will be taken for every 24-hour interval until the reading became constant. The water level in the basin are checked regularly to ensure the same amount of water are present throughout the experiment.

Figure 6: Setup of experiment for porosity test

F. Moisture Content

The shrinkage of an object is defined as the volume that is reduced from its original size. The dimensions of the soil samples are measured after the samples have been cured for 28 days. The volume of the cube mould used for the samples are taken as its original volume. The shrinkage percentage are calculated by subtracting the volume of the cube mould with the volume of the soil sample that has been left to air dry for 28 days[10]. The formula used for shrinkage percentage are shown in Eq.3.1

$$Percentage\ of\ linear\ shrinkage = 1 - \frac{L_D}{L_O} \times 100\% \qquad (3.1)$$

Where,
L_D = Length of the soil after (mm)
L_O = Length of the soil before (mm)

G. Mechanical Test

1) Compressive Strength Test

In order to achieve the main objective of this project, the compressive strength test must be carried out to evaluate the mechanical properties of the stabilized peat soil. The compressive strength test can be carried out by placing the sample on the compression-testing machine and the force needed for the sample to break will be taken. This result will be compared with the control sample to distinguish the effect of introducing bottom ash into the mixture. The compressive test can be carried out according to the standards of EN 12390, BS 1881:115 and ASTM C39.

The compression-testing machine was cleaned thoroughly to ensure no loose dirt are present on the testing plate which might affect the result of the experiment. The specimens are then placed on the centre of the testing plate to ensure the loading applied to the sample are evenly distributed on the surface of the specimen shown in figure 7. A constant loading at a rate of 6kN/s is applied on the sample until it fails[11]. The maximum loading was measured and the compressive strength of the sample can be calculated by dividing the loading force by its surface area.

Figure 7: Compression test for the soil sample

VI. RESULTS AND DISCUSSION

This chapter focuses on the results that have been compiled based on the experiments that have been conducted on the soil sample that uses bottom ash as the industrial waste, addition of Portland-limestone cement and the industrial waste bottom ash as an additive. The bottom ash (BA) and PLC with sand sample is to be compared with samples with Sand and PLC. The experimental works that have been performed are mainly to study the effect of introducing industrial waste which is bottom ash and several additives in order to compare the compressive strength of soil sample as well as the physical properties. The results of this study are tabulated in tables and graphs to properly convey the outcome.

Soil stabilisation by using binder materials in weak soil to improve its geotechnical properties such as compressibility, strength and permeability, and it depends on the soil property and the component of stabilisation binders, such as cement, lime, fly ash, blast furnace slag, calcium sulphate, and gypsum. This study will use the industrial wastes namely bottom ash for the stabilisation of soil for the purpose of construction of buildings and roads. Peaty soil is a major challenge in the field geotechnical engineering. In order to resolve the problem of this peaty soil, this study is going to improve the strength of peat soil by adding the bottom ash along with Portland cement.

A. Physical Properties

The tests that have been carried out to study the physical properties of soil sample are density, specific gravity, moisture content, porosity and shrinkage.

1) Density Test

The density of the samples is calculated by dividing the total mass with its total volume. The sample with a higher density value will have a greater mass with the same volume compared to the soil sample which have a smaller mass shown in figure 8. An object with higher density tends to be more rigid and solid than an object with a lower density. After the samples have been left to air dry in 28 days, the measurement of the samples is taken as well as its mass. The data for density of treated soil sample can be illustrated in Table 3.

Table 3: Data for density of treated soil

Variation of soil sample (Peat and PLC is common in all)	Dimensions			Average Mass in kg	Average density kg/m3
	L	H	B		
BA+SAND+PCA	100	100	100	1.487	1487
SAND+PCA	99.5	99.6	99.6	1.617	1638
BA+WPCA	98.3	98.2	96.8	0.801	857
SAND+WPCA	95.6	95.9	91.9	0.929	1102

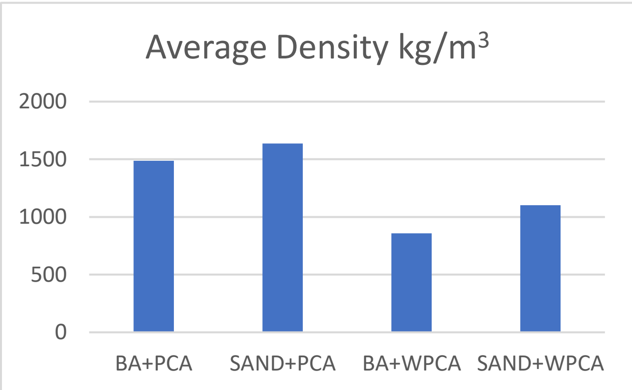

Figure 8: Density of treated soil

Based on the table above, the BA+PCA and SAND+PCA samples have an average density of 1487kg/m3 and 1638kg/m3 while the sample with SAND+WPCA and BA+WPCA have an average density of 857kg/m3 and 1102kg/m3 respectively. The soil sample treated with PCA have a higher density compared to sample treated with WPCA. This is due to the role of PCA that uses the water content in the sample to undergo hydration process which produces new materials. Meanwhile, WPCA does not have the same properties as PCA and therefore it will not remove the excess water in the sample mix. The water content that exists in WPCA samples will dry up and form voids which decreases the density of the sample. Thus, the PCA samples will be more compact and solid compared to sample treated with WPCA.

2) Specific Gravity

The specific gravity tests of soil samples are indicated with different variations of sample with peat, bottom ash, sand, PLC, process control agent (PCA) without process control agent (WPCA). According to Kifli [17], the average specific gravity of peat soil is 1.18. The summarized value of specific gravity for this project can be illustrated in Table 4.

Table VI: Specific gravity, GS for each soil sample

Variation of soil sample (Peat and PLC is common in all)	Average mass (kg)	Average density (kg/m3)	Averag e specific gravity
BA+SAND+PCA	1.487	1487	1.487
SAND+PCA	1.617	1638	1.638
BA+WPCA	0.801	857	0.857
SAND+WPCA	0.929	1102	1.102

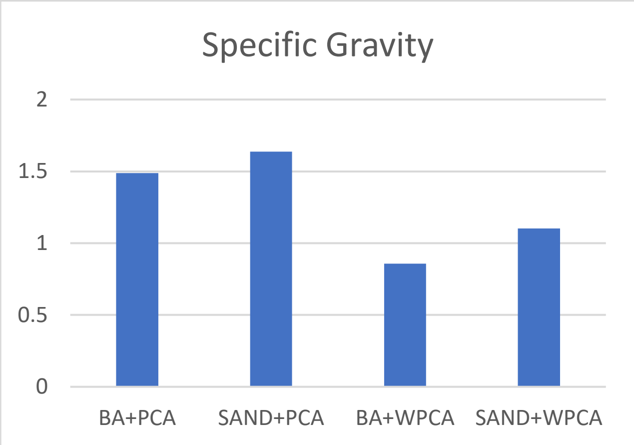

Figure 9: Average specific gravity of stabilized peat

Based on the specific gravity that has been calculated, the soil sample with Process Control Agent (PCA) with sand have the highest specific gravity (1.638), followed by Process Control Agent (PCA) with bottom ash (1.487). The value of specific gravity of the soil can be calculated by dividing the density of the sample with the density of water. According to the data of specific gravity, it is clearly shown that the both samples treated with PCA have a higher value of specific gravity than WPCA samples shown in figure 9. The difference in specific gravity indicates that the water content in the PCA samples have undergo hydration process.

3) Moisture Content

The moisture content of the samples is calculated in order to study the percentage of water present within the soil sample. The data of mass of soil sample obtained from the oven test are used to calculate the percentage of moisture content and the difference can be studied. Peat soil itself are known to have high moisture content due to its porous characteristic and the presence of fibrous material and organic matter. The porous properties of peat soil allow more water to be absorbed and thus creating a weaker bond structure of the soil in figure 10. The percentage of moisture content for each variation of samples are tabulated in the Table 5.

Table 5: Moisture content of soil sample in percentage

Variation of soil sample (PEAT+PLC)	Average mass (kg)	Average moisture content(%)
BA+PCA	1.48 7	27.37
SAND+PCA	1.31 7	24.50
BA+WPCA	1.22 3	8.7
SAND+WPCA	1.52 1	28.14

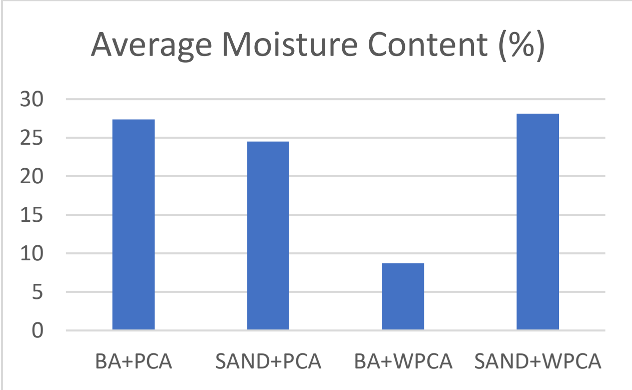

Figure 10: Average moisture content for stabilized peat

4) Porosity

Porosity of soil can be defined as the volume of void that exist in the soil sample. For this project, the porosity of the stabilized soil samples can be calculated by studying the ability of the soil to absorb water. In order to investigate the water absorption ability of the soil, the samples are placed on top of a metal rod in a basin. The basin is then filled with water until it reaches between 1 to 2mm above the metal rod. This is to ensure that the sample is only exposed to water on one side only in figure 11. The weight of the samples is measured using an electronic balance for every 24-hour interval until the weight of the sample become constant as it reaches the limit of the sample to absorb water. The porosity of soil sample with peat, PLC, PCA and bottom ash as shown in the following Figure 4.4. The average water absorption of the soil samples is tabulated in Table 6.

Table 6: Average water absorption percentage of BA samples

Variation of soil sample (PEAT+PLC)	Averaze initialmass (kg)	Average Final mass(kg)	Average water absorption (%)
BA+PCA	1.366	1.669	20.18
SAND+PCA	0.843	1.199	20.23
BA+WPCA	0.890	1.042	19
SAND+WPC A	0.754	1.359	30

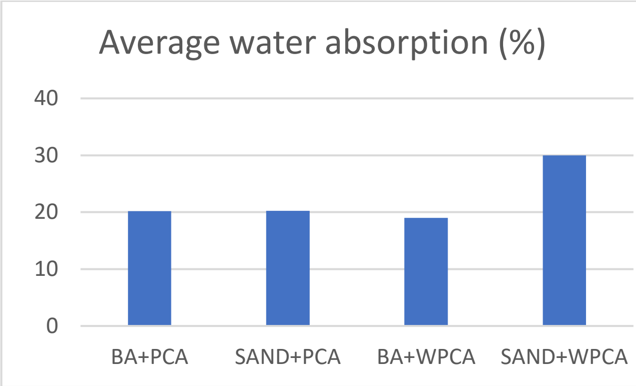

Figure 11: Average water absorption percentage of BA samples

5) Atterberg's Limit

Liquid Limit and Plastic Limit were conducted on the soil without and with bottom ash. The different proportions of bottom ash added in the soil was 0%, 5%, 10%, 15%, 20%, 30%. This test is done to determine the plastic limit and liquid limit of soil as per IS:2720 (Part 5) – 1985 in figure 12 and figure 13.

6) Liquid Limit

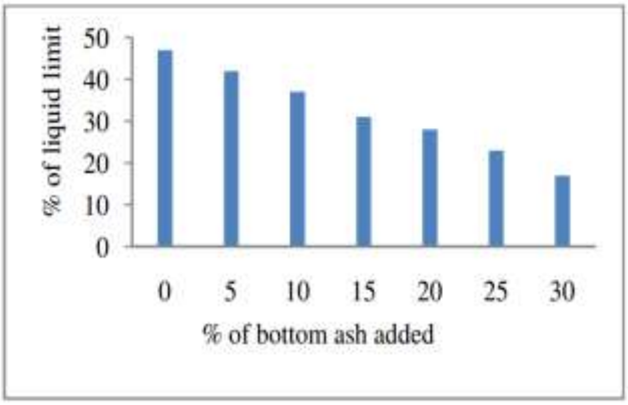

Figure 12: Liquid limit

7) Plastic Limit Test

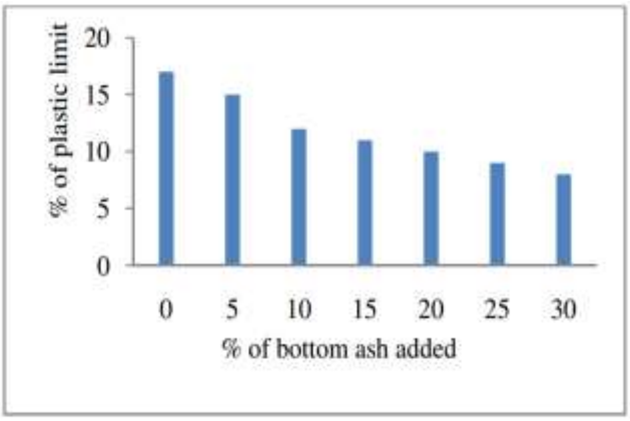

Figure 13: Plastic limit

B. Mechanical Properties

1) Compressive Strength Test

The compressive strengths of the soil samples are the main objective that needs to be studied in this project in order to distinguish the effect of the materials used in terms of its strength. The samples are tested for its compressive strength after air cured for 28 days. Before beginning the test, any loose dirt on the machine plate was removed to reduce the degree of error while conducting the testing. The test samples are placed on the middle of the plate in order to get a more accurate reading of compressive strength. Then, the loading is applied at a constant rate of 6kN/s to the test sample until the specimens have failed. The compressive strength of the samples can then be calculated by dividing the maximum axial loading with its surface area in figure 14. The average compressive strengths of the soil samples are tabulated in the Table 7.

Table 7: Average compressive strength of soil

Variation of soil sample	Average maximum axial-loading (kN)	Average compressive strength (N/mm^2)
BA+PCA	35.0	3.5
SAND+PCA	36.0	3.6
BA+WPCA	25	2.5
SAND+WPCA	14	1.4

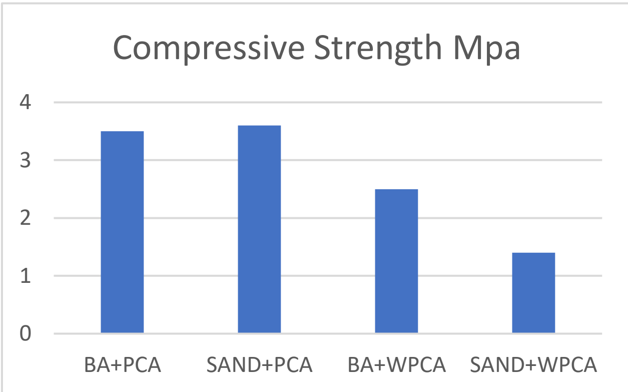

Figure 14: Graph of compressive strength for BA+PCA

VII. CONCLUSION

In conclusion, the objectives of this study can be successfully determined. Bottom ash acts as a better filler compared to sand based on the discussed physical and mechanical properties. The formation of calcite in the sample with bottom ash contributes to the increase of compressive strength and the compactness of the peat soil compared to the samples with sand. This indicates that bottom ash produces better results as the filler based on the strength improvement of peat and the zero value of shrinkage percentage. Next, the role of chemical additives in the sample mix are studied which resulted in PCA being the best chemical additive to improve the strength of stabilized peat. The function of PCA in allowing hydration process to occur in the sample while removing the excess water is proven to produce a more solid and stronger soil than WPCA samples. Furthermore, the compressive strength of the peat soil can be improved by using bottom ash as the filler and PCA as the chemical additive as it has better compressive strength compared to using sand and WPCA. The samples with WPCA show zero compressive strength as the function of WPCA does not suit the role in producing a stronger soil structure of peat. According to the physical appearance of the samples treated with WPCA, the soil is examined to be weaker than samples treated with PCA. WPCA as a foaming agent does not remove the excess water content in the sample resulting in a much poorer outcome of compressive strength."

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