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Potential of Soil Stabilization Using Ground Granulated Blast-Furnace Slag (GGBS)

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ABSTRACT- Natural delicate soil also known as organic soft soil (OSS) has extensive negative geotechnical properties, for example, high water content, low shear strength, high natural matter, and low bearing limit and thus a critical cutting off high compressibility happens that makes it as one of the most troublesome soils for building structures over its normal state. As a result of these geotechnical issues of natural delicate soil, improvement instrument is so fundamental when the natural delicate soil exists to manage it as a dirt establishment. In this review, the physical and mechanical properties of the natural delicate soil are talked about. This principal objective of this study is to work on the strength of natural delicate soil by adding modern waste as a filler and concrete as a folio. Natural delicate soil are known to have a frail strength and an exceptionally high settlement issue. Notwithstanding, past explores have demonstrated the way that the strength of natural delicate soil could be improved by utilizing soil adjustment strategy. In this review, Soil adjustment has turned into the significant issue in development designing and the explores in regards to the viability of involving modern squanders as a stabilizer are quickly expanding. This concentrate momentarily depicts the reasonableness of the GGBS to be utilized in the nearby development industry in a method for limiting how much waste to be arranged to the climate causing natural contamination. A few structural designing lab tests are led to review the geotechnical properties of GGBS and strength gain when blended in with nearby mud test. An alternate extent of GGBS and soil test restored for 7 days brings about a strength gain. A superior comprehension of the properties of GGBS is acquired from the review and the tests demonstrates a superior strength and better properties of delicate soil test when settled. The impact of GGBS on the physical and geotechnical qualities of the dirt, for example, Atterberg limits, compaction boundaries (most extreme dry thickness (MMD) and ideal dampness content (OMC)) and soil strength (unconfined compressive strength (UCS)) has been researched. GGBS was included different rates (3, 6, 9 and 12%). Improvement levels were demonstrated by UCS testing did on examples following 7 days of relieving.

KEYWORDS- Compressive Strength, GGBS, Organic Soft Soil, Strength, Stabilization

I. INTRODUCTION

Delicate soil is thought of as perhaps of the most hazardous soil in structural designing due to the serious level of compressibility and unsteadiness, low porousness, low compressive strength (under 40kpa) and potential to enlarge with high water content as it contains minerals, for example, montmorillonite that can retain water. Hence, when delicate soil is experienced in areas assigned for structural designing activities, the conceivable elective arrangements can be either leave the site, or eliminate and supplant the dirt. In any case, these arrangements are not generally plausible and they can be costly. Consequently, specialists have researched further developing the designing properties of the local issue soil by a few techniques, in particular soil adjustment. Soil adjustment is the method involved with revising the physical and geotechnical qualities of the delicate soil, for example, strength, porousness, sturdiness and compressibility either precisely or by the expansion of synthetic stabilizers to be appropriate for development and satisfy designing plan guidelines including permanency (Makusa, 2012). Concrete and lime are the main customary stabilizers and have been examined by numerous analysts.

A. Aim & Scope

In light of the significant properties of natural delicate soil, for example, high compressibility, low shear strength and high dampness content attributes acquired from the hypothetical examination and assessment of natural delicate soil reaction to stacking, the accompanying goals are gone ahead for this exploration:

- To measure some important engineering and index properties of organic soft soil.
- To study the effect of different percentages of GGBS on organic soft soil in term of its strength and pH.

Nonetheless, the meaning of this exploration is to track down approaches to balancing out and further developing natural delicate soil targeting tackling the issues relating minimal land. This will facilitate information on the way of behaving of natural delicate soil with the end goal of geotechnical designing applications.
The examination covers the adjustment of natural delicate soil by the utilization of admixture like lime. Designing and record properties of natural delicate soil for example; dampness content, atterberg limit, explicit gravity and not entirely set in stone before unconfined compression test (UCT) had been directed.

B. General Properties of Peat

Organic soft soil, like any other soil types has its own physical, chemical and engineering properties. Organic soft soil has been identified as a kind of soil that owns a wide range of physical properties such as specific gravity, water content, texture, colour and density among others. Hobbs (1986) stated, those physical properties should be included in a full description of the organic soft soil. They are influenced by the main components of the formation such as mineral content, organic content, moisture content and air respectively. However, whenever one of these components changes, it will result in the change of the whole physical properties of organic soft soil. This variation in the characteristics of organic soft soil is related to differences in climate, water level, aging and the quantity of inorganic soil deposited during organic soft soil accumulation.

II. EXPERIMENTAL PROCEDURE

A. Materials

1) Organic Peat Soil

“The soil was collected from the shoulders of the River Sinsh which is situated in Duderhama to the Sonamarg. The soil was taken from a depth of about 30cm and 50cm below the ground level. The extracted samples were placed in sealed plastic packs 20-25kg each before transporting to the research laboratory. The specimens were taken to measure the in-situ moisture content while, the other sub-samples of the soil were dried in the oven at 110C o.Compaction parameters measured in accordance to BS EN ISO 1377-2 and 4:1990 (British Standard, 1990) respectively. The chemical properties of the soil were indicated by conducting a chemical analysis. The characteristics of the soil utilised in this research are shown in Table 1

Table 1: The Characteristics of the soil utilised

Chracteristics	Value
In-Situ Moisture Content	37.5
Liquid Limit LL %	39.5
Plasticity Index PI	18.37
Sand %	12.07
Silt %	75.03
Clay %	12.90
Specific Gravity(SG)	2.67
ϒ d max Mg/m^3	1.59
Optimum Moisture Content	22
pH	7.78
Organic Matter Content %	7.95
Unconfined Compressive Strength qu(kpa)	134

2) Ground Granulated Blast Slag (GGBS)

GGBS is by-product materials produced from manufacture of iron. It mainly consists of lime, alumina, and silicate. There are similarity between GGBS and ordinary Portland cement in oxides types but not the percentage (Sha and Pereira, 2001; Oner and Akyuz, 2007). During the production of GGBS, its cementitious characteristics increases because molten slag chills rapidly after leaving the furnace. The rapid chilling leads to decrease in the crystallisation and transforms the molten slag into a glassy material (Thanaya, 2012). The chemical composition of GGBS utilised in this research is given in Table 2.

Table 1: The chemical characteristics of GGBS used in this study

Items	CaO	SiO	Al_2O_3	MgO	Fe_2O_3	SO_3	K_2O	TiO_2	pH
GGBS	40.13	37.73	5.75	4.26	0.01	0.0	0.61	0.65	8.5

Figure 1: sample of GGBS

3) Mix Proportion

GGBS used in this study was mixed with the soft soil in various proportions (0, 3, 6, 9 and 12%) by the dry weight of the soft soil to obtain the optimum amount for stabilisation.

Table 3: Mix Proportion of Sand Sample

Proportion	Peat (by parts	Portland Limestone Cement (PLC) (by parts)	Sand	Volume of Water (litres,L)
Sample 1-10	5	3	5	3.5

Table 4: Mix Proportion for Bottom Ash Sample

Proportion	Peat (by Parts)	Portland Limestone Cement (PLC) (by parts)	GGBS + Sand By parts	Volume of Water (litres,L)
Sample 1-10	5	3	5	3.5

III. RESEARCH METHODOLY

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

1) 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. The weight of the sample is measured using an electronic balance.

2) 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

3) Soil pH Test

pH tests has been conducted in order to evaluate the alkalinity of untreated and stabilized organic soft soils in order to establish the stability of stabilizer (lime)for stabilizing organic soft soil. Laboratory digital pH meter was used in the determination of pH of both stabilized and untreated organic soft soil samples. Linking the pH with electric voltage, digital pH meter measured the pH of soil based on the voltage indicator.

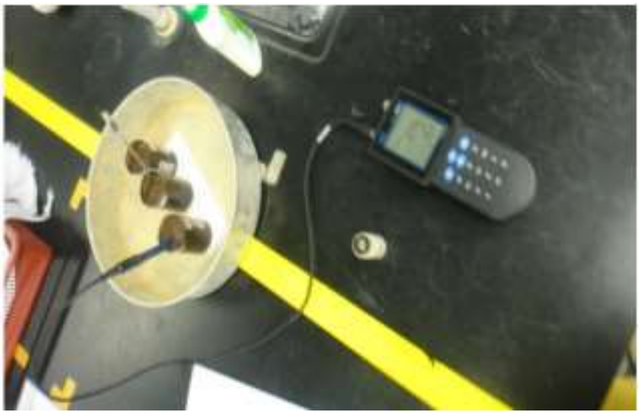

Figure 2: Determination of organic soft soil pH

4) Moisture Content

Water is present in most naturally occuring soil, including organic soft soil. The amount of water, expressed as a proportion by mass of the dry solid particles known as the moisture content, has a profound effect on soil behavior. Therefore, a soil is “dry” when no further water can be removed at a temperature not exceeding 110ºC. Moisture content is required as a guide to classification of natural organic soft soils and measure on samples used for laboratory test. The moisture content of organic soft soil samples has been determined per the procedures outlined in BS 1337: Part 2: 1990: 3.2. This method is known as „oven-drying‟ method. The moisture content of the soil is expressed as a percentage of its dry mass.

5) Porosity

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. 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. In order to calculate the porosity of the sample, the concept of water absorption.

6) Shrinkage

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. The formula used for shrinkage percentage are shown in Eq.3.1.

$$Percentage\ of\ linear\ shrinkage = 1 - \frac{L_D}{L_0} \times 100\% \quad (3.1)$$

Where,
L_D = Length of the soil after (mm)
L_0 = Length of the soil before (mm)

B. 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 organic soft 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. A constant loading at a rate of 6kN/s is applied on the sample until it fails. The maximum loading was measured and the compressive strength of the sample can be calculated by dividing the loading force by its surface area.

C. Flow Chart of the Research

Figure 3: Summarized Flow Chart of the Research

IV. METHODOLOGY

The tests that are carried out includes both physical and mechanical properties of the soil sample which are the density, specific gravity, moisture content, porosity, shrinkage and the compressive strength. The organic soft soil is extracted from Nunar, Ganderbal which is stabilized using GGBS as the industrial waste, Portland-limestone cement as the binder and Process control agent (PCA) as the chemical additive. The properties of the stabilized soil will then be compared with the control soil sample mixed with sand to study the effect of implementation of the industrial waste which is bottom ash with the addition of chemical additive.

V. RESULTS AND DISCUSSION

A. 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. 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 5.

Table 5: Data for Density Of treated Soil

Variation of Soil Sample Organic Soft Soil is common	Dimension in mm			Average Density (kg/m^3)	Average Specific Gravity
	L	B	H		
GGBS+SAND+PLC	100	99	100	18.20	1.8
OSS+SAND+PLC	94	90	92	15.49	1.55

1) Discussion

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.

According to the achieved results, samples that are mixed with sand have a higher average density than bottom ash. The smaller particle size of sand fills up the void in the sample efficiently compared to the larger particle size of bottom ash. The smaller voids in the sample mix with sand increases the weight of the sample and thus producing a higher average density. Thus, the sample with the lower average density tends to have a lower compressive strength compared to the sample with higher density.

B. Specific Gravity

The specific gravity tests of soil samples are indicated with different variations of sample with peat, GGBS, sand, PLC. According to Kifli (2016), the average specific gravity of peat soil is 1.18. The summarized value of specific gravity for this project can be illustrated in Table 6.

Table 6: Specific Gravity, Gs for each soil sample

Variation of soil sample Organic soft soil (OSS) is common	Average mass (kg)	Average density (kg/m3)	Average specific gravity
GGBS+SAND+PLC	1.82	1820	1.8
OSS+SAND+PLC	1.549	1549	1.55

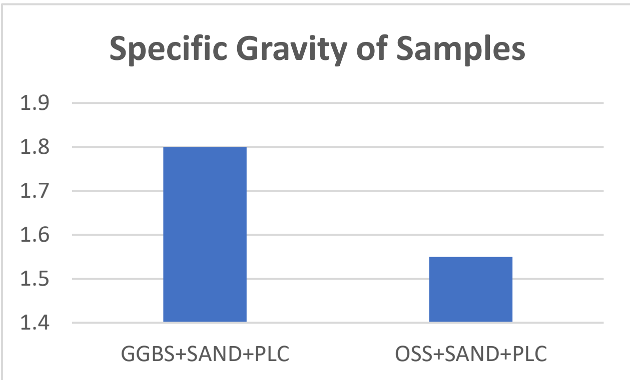

Figure 4: Average Specific Gravity Of stabilized Peat

1) Discussion

Based on the specific gravity that has been calculated, the soil sample with sand and GGBS have the highest specific gravity (1.8), followed by Process Control Agent (PCA) with simple sand (1.55). 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. The difference in specific gravity indicates that the water content in the PCA samples have undergo hydration process.

C. Atterberg Limits

The results of Atterberg limits of soil treated with 0, 3, 6, 9 & 12% by dry weight of the soft soil is shown in Figure 1. The figure shows that increasing the GGBS content resulted in decrease in the liquid limit and increase in the plastic limit. The Plasticity index decreased from 18 to below 15. These observations are in consistent with the results indicated by (Akinmusuru, J.O. 1990; Ouf , 2001; Yadu & Tripathi, 2013).

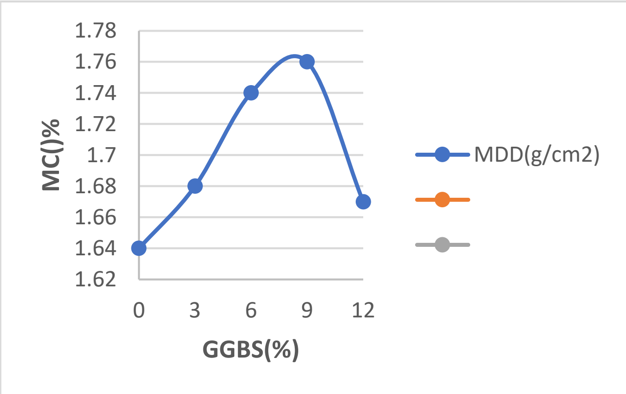

Figure 5: Atterberg Limits after GGBS Treatment

D. Compaction Parameters Test

This test aims to indicate the maximum dry density (MDD) and the optimum moisture content (OMC) for untreated soil and soil treated with various percentage of GGBS. The values of MDD and OMC are significantly important as they are used in the preparation of samples for other tests such as unconfined compressive strength, compressibility, and swelling potential. Standard proctor tests were conducted on the soft soil incorporating various percentages of GGBS (0, 3, 6, 9 & 12%). The results of the compaction tests which are shown in Figure 2 and 3 (a & b) indicate that increase GGBS content caused increase in the MDD and decrease in the OMC with increase the GGBS content up to 9%. By increase the GGBS content further to 12%, the OMC and the MDD increased and decreased respectively. This trend similar to that observed by (Akinmusuru, 1990; Yadu & Tripathi, 2013; Padmaraj & Chandrakaran, 2017). The increase in the MDD can be attributed to the specific gravity of GGBS (2.89) which is higher than that of the soil (2.67). While, the decrease in the OMC with increase GGBS content may be the result of decreasing the quantity of free silt and clay fraction with the addition of GGBS, thus the smaller surface area required less water (Yadu & Tripathi, 2013). However, the behaviour at 12% GGBS may be due to the higher amount of GGBS in the soft soil and decrease in the amount coarse materials so make it more difficult to attain good compaction (Akinmusuru, 1990).

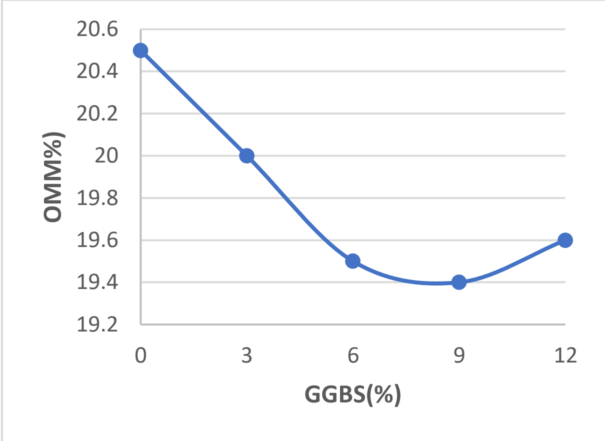

Figure 6: Effect of GGBS on the OMC

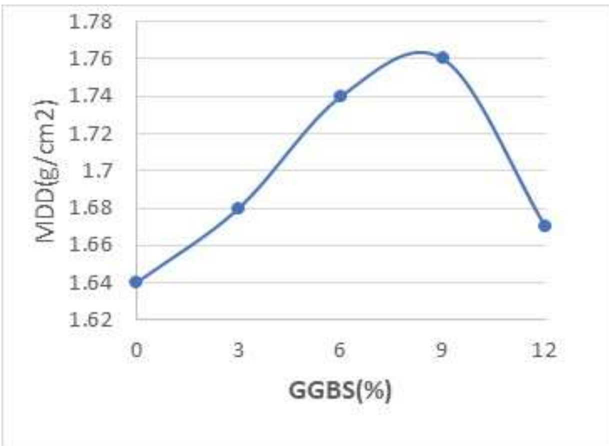

Figure 7: Effect of GGBS on the MDD

E. Unconfined Compressive Strength

This test represents a useful method to measure the shear strength of treated soil as it provides an indication of the effectiveness of the stabiliser agent used. The results obtained on soil stabilised with (0, 3, 6, 9 and 12% GGBS by the weight of the dry soil) after curing for 7 days.

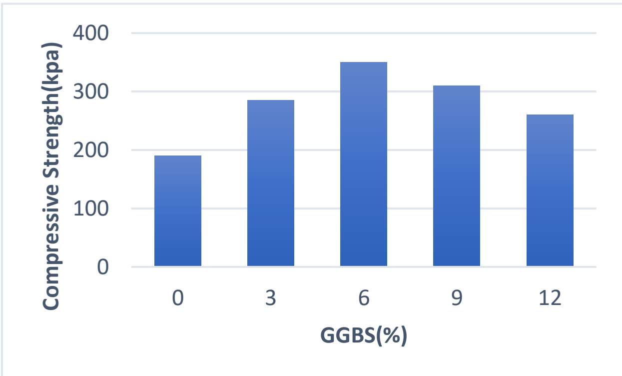

Figure 8: Relationship between UCS and GGBS percentages in 7 days curing

1) Discussion

The figures show that GGBS can enhance the strength of the soil up to a content of 6%. At contents of 9% and 12%, the strength decreased. The improvement can be explained by the development of cementitious compound between the

GGBS and the soil (Yadu & Tripathi, 2013). It has been reported by the previous researchers (Higgins, 2005; Nidzam and Kinuthia, 2010) that the GGBS has a minimal degree of hydration due to its low pH and for it to be effective in terms of soil stabilisation it should be activated with a suitable activator in order to break its glassy phase. Thus in the future work, the second stage of optimisation process will be carried out involving the activation of GGBS with alkaline sulphate activator such as cement kiln dust (CKD). The reduction in the strength with 9% and 12% GGBS may have resulted from the introduction of an excessive amount of GGBS to the soil that led to the formation of weak bonds between the soil and the cementitious compounds obtained (Yadu & Tripathi, 2013). This study has been carried out to investigate the effect of GGBS on the physical and engineering properties of the soft soil. The soft soil selected for this study was classified according to the USCS as CI. The soft soil was mixed with GGBS at different percentages (0, 3, 6, 9 & 12%). The results indicate that the use of GGBS gave an improvement in the physical and strength characteristics of the soil. With the addition of GGBS to the soil, the Plasticity Index decreased while MDD and OMC increased and decreased respectively. Based on the UCS tests, the optimum amount of GGBS was 6% as it increased the strength by about 80% of that of soft soil. In spite of the improvement indicated in this research, it was not sufficiently high as GGBS is a latent hydraulic material and needs an activator to break its glassy phase.

VI. CONCLUSION

A Soft soil has significant problems, most importantly poor shear strengths and high compressibility. Being present in engineering projects locations, remediation becomes essential to prevent excessive post- construction settlement and to avoid insufficient bearing capacity. Chemical soil stabilisation is the most popular technique for remediation of such poor ground conditions. Cement and lime are the common traditional stabilisers that have been incorporated for stabilising the soil. However, the high environmental and financial cost associated with cement and lime raise the need to identify new more sustainable alternatives. Thus, researchers have investigated the utilisation of waste and by-product materials that possessed pozzolanic or hydraulic characteristics as a replacement for cement and lime. This paper presents the results of a laboratory study on the stabilisation of silty clay soil collected from the shoulders of the Government Hospital, Nunar, Ganderbal, J&K using a ground granulated blast furnace slag (GGBS). The influence of GGBS on the physical and geotechnical characteristics of the soil such as Atterberg limits, compaction parameters (maximum dry density (MMD) and optimum moisture content (OMC)) and soil strength (unconfined compressive strength (UCS)) has been investigated. GGBS was added in various percentages (3, 6, 9 and 12%). Improvement levels were indicated by UCS testing carried out on specimens after 7 days of curing. Results indicated increase in the maximum dry density increased and decrease in the optimum moisture content with increase the GGBS content up to around 9% after that .i.e. at 12% the MDD and OMC gave reversed trend. In term of Atterberg limits, the liquid limit decreased, the plastic limit increased and plasticity index decreased with increase GGBS content. Based on the strength result obtained from UCS test, 6% of GGBS by the dry weight of the treated soil is the optimum binder to stabilise the soft soil.

Soft soil is considered as one of the most problematic soils in civil engineering because of the high degree of compressibility and instability, low permeability, low compressive strength (less than 40kpa) and potential to swell with high water content as it contains minerals such as montmorillonite that are able to absorb water (Bell, 1992; Rajasekaran, 2005; Nordin, 2010; Mohamad et al., 2015). Therefore, when soft soil is encountered in locations designated for civil engineering projects, the possible alternative solutions can be either abandon the site, or remove and replace the soil. However, these solutions are not always feasible and they can be expensive. Thus, researchers have investigated improving the engineering properties of the native problem soil by several methods, most importantly soil stabilisation (Makusa, 2012; Jafer et al., 2015; Kumar and Kazal, 2015). Soil stabilisation is the process of amending the physical and geotechnical characteristics of the soft soil such as strength, permeability, durability and compressibility either mechanically or by the addition of chemical stabilisers to be suitable for construction and meet engineering design standards including permanency (Makusa, 2012). Cement and lime are the most important traditional stabilisers and have been investigated by many researchers (Miura et al., 2002; Al-Tabbaa, 2003; Raoul, et al., 2010; Farouk and Shahien, 2013; Kitazume and Terashi 2013 and Önal, 2014). However, cement production has many drawbacks such as carbon dioxide emission (CO_2), energy consumption and natural resources exhausting. The production of 1 tonne of cement leads to consume 1.5 tonnes of natural resources, consumes an energy of 5.6Gj/tonne and emits 0.9 tonne of CO_2. Thus, the manufacture of cement is responsible for the production of about 5% of total anthropogenic CO_2 emission (O'Rourke et al., 2009).

This study has been carried out to investigate the effect of GGBS on the physical and engineering properties of the soft soil. The soft soil selected for this study was classified according to the USCS as CI. The soft soil was mixed with GGBS at different percentages (0, 3, 6, 9 & 12%). The results indicate that the use of GGBS gave an improvement in the physical and strength characteristics of the soil. With the addition of GGBS to the soil, the Plasticity Index decreased while MDD and OMC increased and decreased respectively. Based on the UCS tests, the optimum amount of GGBS was 6% as it increased the strength by about 80% of that of soft soil. In spite of the improvement indicated in this research, it was not sufficiently high as GGBS is a latent hydraulic material and needs an activator to break its glassy phase.

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