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The Effect of Geopolymer to the Compaction Parameter of Laterite Soil

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Abstract: Laterite soil is used as a compacted soil which will be stabilizing by adding different percentage of geopolymer. Geopolymer is a material that can easily react with water lead to results into a powerful compaction aid and giving a higher density for the same compactive effort. Hence, geopolymer is choosed to mix with laterite soil in order to improve the workability of the soil. Different percentage of geopolymer 5%, 10%, 15% and 20% were used. This research was carried out in an attempt to know the best percentage of geopolymer that is suitable to improve compaction parameter of laterite soil. Based on the results, it is proved that the laterite soil mix with 15% of geopolymer give the best value of dry density and moisture content of soil with the heavy and standard compaction effort. The outcome of this study presents a positive results due to the potential of geopolymer to fulfill spaces that exist between soil particles.

Key words: Laterite soil · Geopolymer · Maximum Dry Density (MDD) · Optimum Moisture Content (OMC)

INTRODUCTION

Soil stabilization is the alteration of one or more soil properties, by mechanical or chemical means, to create an improved soil material possessing the desired engineering properties. Based on ASTM [1], the main purpose of soil stabilization include increased the strength of an existing soil to enhance its load bearing capacity, permeability improvement and enhancement of soil resistance to the process of weathering and traffic usage among others.

Chemical technique is commonly as soil stabilization approach, because it produces a better improvement of soil with higher strength and durability than mechanical and physical techniques. In chemical stabilization technique, it is more dependent on reaction between chemical additives and soil particles. This reaction will then produce a strong network that bind the soil grains.

Geopolymer is an alkali-activated aluminosilicate binders which are formed by reacting raw solids which are rich in silica and alumina with a solution of alkali or alkali salts. Feng and Ven[2] stated that when this two material are mix, it will producing a mixture of gels and crystalline compounds that eventually harden into a new strong matrix. Previous researcher Wang and Yan [3] mentioned that the polycondensation reaction occurs in a high alkaline environment that reorganizes alumina and silica in a more stable Si–O–Al type structure, resulting in materials with high mechanical strength and chemical stability.

Referring to previous study, Douglas *et al.* [4] and Cristelo *et al.* [5] mentioned thatgeopolymers are inorganic binders consisting of two components which are a very fine and dry powder and a syropy, highly alkaline liquid. In order to produce a mixture of molasses like consistency which is then reacted with the desired waste or aggregate, the liquid and powder portions are mix together [4].

Previous researcher, Cristelo *et al.* [5] stated that in geotechnical applications, alkaline activation which is geopolymeric binder of fly ash was tested for soil improvement since waste material was obtained as binder in most of other geopolymer applications. Alkaline-activated materials showed better performance since durability and stability can be increased, improvement from mechanical aspect compared to cement and also improved bond between the soil particles and binder [6].

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According to ASTM [1] and Davidovits [7], mineral polymers are class of amorphous to semi-crystalline materials formed at near ambient temperature. Chemically, mineral polymers consist of cross linked units of AlO^4 and SiO^4 tetrahedral, where charge balancing cations (Na^+, k^+, Li^+, Ca^{2+}, Ba^{2+}, $H3O)^+$ are provided by alkali metals. Chemical stabilization includes the use of chemicals and emulsions as compaction aids to soils, as binders and water repellents and as a means of modifying the behavior of soil. Chemical stabilization can aid in dust control on roads and highways, particularly unpaved roads, in water erosion control and in fixation and leaching control of waste and recycled materials [8].

Experimental Work

Preparation of Soil Sample: This research methodology begins with identifying a group of soil from selected field workin order to use those as sample. The laterite soil was taken from DamansaraPerdana area. Then, basic properties test of natural soil were carried out. In preparation of geopolymer, Sodium Hydroxide (NaOH) pellets were added to water to obtain sodium hydroxide solution. Then, low calcium content (class F) fly ash and the alkaline activator (NaOH) was added and mixed together to form the geopolymer in a binder state.

Basic Properties Test: Experimental work were mainly carried out in Geotechnical Laboratory of Faculty of Civil Engineering UiTM, where the test were performed accordance with British Standard BS 1377-2:1990. The Basic Properties Tests were carried out to determine the Physical Properties of natural soil such as Particle Size Distribution Test, Atterberg Limit Test and Specific Gravity Test.

Compaction Test: Compaction test have been done using Standard Proctor Test in order to obtain optimum moisture content (OMC) and maximum dry density (MDD) of soil. This test procedure is based on BS1377:Part4:1990. The soil was oven dried and sieved down before being mixed with various proportion of geopolymer and water content. Then compaction test was carried out. The result of optimum moisture content (OMC) and maximum dry density (MDD) for natural soil and soil mixture with different percentage of geopolymer(5%, 10%, 15% and 20%) were analyzed. Two different types of compaction test were carried out which is British Standard Light Test (BSL) and British Standard Heavy Test (BSH) as shown in Table 1.

Table 1: Comparison of compaction test procedure [9]

Test Procedure	Rammer (kg)	Falling Height (m)	No. of Blow	No. of Layer	Compaction Force (kNm/m)
BSL	2.5	0.3048	27	3	605.9
BSH	4.5	0.457	27	5	2723.5

RESULTS AND DISCUSSION

This part present the results from the experimental work that have been done. There are two types of test that have been carried out which are physical properties test and compaction proctor test. The physical properties tests which have been conducted are sieve analysis test, Atterberg limit test, specific gravity test and compaction test. It is important to know the characteristic and properties of natural laterite soil for the future development on that soil. Table 2 show the physical properties of natural laterite soil from this study.

Table 2: Physical properties of natural laterite soil

Parameters	Results
Grain Size Analysis	% Gravel: 0.88% % Sand: 77.48% % Fine: 21.64%
Atterberg Consistency Limits	LL: 58.61% PL: 52.46% PI: 6.15%
Specific Gravity	G: 2.59

On the other hand, compaction test were performed in order to know the optimum moisture content and maximum dry density of laterite soil. Optimum moisture content is important to be determined in order to know how much percentage of water can be sustain by the soil sample. In order to get the best and effective results, five soil samples have been prepared in this research. For sample number 1, the percentage of geopolymer that had been used is 5%, followed by sample 2, sample 3 and sample 4 which are 10%, 15% and 20% of geopolymer. The required percentage of water was added into the soil sample. The amount of soil that was used about 2500g.

British Standard Light Test: Figure 1 show the graph of dry density and moisture content of natural laterite soil and laterite soil mix with different percentage of geopolymer. From the results, it was observed that there is exist a strong relationship between dry density, moisture content and geopolymer. The soil with 15% geopolymer give the higher value of dry density, which the maximum dry density for that mixture is 1.91 Mg/m^3 and 13.87% of moisture content. Meanwhile, for the soil

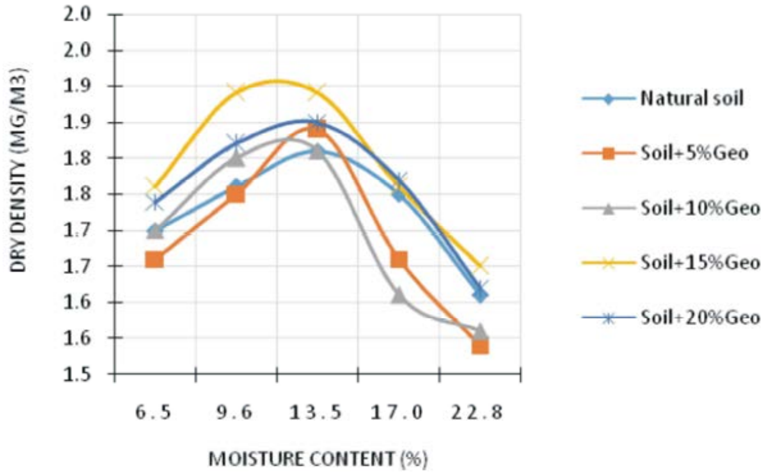

Fig. 1: Dry density and moisture content of natural laterite soil and laterite soil mix with different percentage of geopolymer for British Standard Light Test

mixture with 20% of geopolymer show less maximum dry density and optimum moisture content compare to soil mixture with 15% of geopolymer which 1.85 Mg/m^3 and 13.67%. Laterite soil which has been added with geopolymer shows the increment in dry density and moisture content value compare to natural laterite soil. This is due to the action of the sodium hydroxide in the geopolymer which change the mineral in soil by alkaline attack.

British Standard Heavy Test: Furthermore, Figure 2 show the dry density and moisture content of natural laterite soil and laterite soil with different percentage of geopolymer for British Standard Heavy test. Based on the results, it is show that the value of dry density at first of compaction for natural laterite soil high when compared to soil mix with geopolymer. However, at the third stage of compaction, the soil that mix with 10% and 15% of geopolymer shows high value of dry density compared to other soil sample which are 2.06 Mg/m^3 and 2.07 Mg/m^3. Meanwhile, for soil mixture with 20% of geopolymer only shows a little increment of dry density which are 2.01 Mg/m^3. It is show that the geopolymer gels that have been added to the soil specimen tend to form more homogeneous and compact microstructure of soil.

Comparison between British Standard Light Test and British Standard Heavy Test: For this study, two different types of compaction effort test have been carried out which were British Standard Light Test and British Standard Heavy Test. From the results, it show that the geopolymer become a factor that influence the value of dry density and moisture content of soil mixture. Besides that, the compaction effort also become an important factor that effect the parameter of compaction. This is proved in Figure 3, Figure 4 and Figure 5 which shown the value of dry density and moisture content for both types of compaction. From Figure 3, the graph present that the value of dry density for British Standard Heavy Test are much higher compare to British Standard Light Test (the dotted line). It is because the weight of hammer, compaction force and drop height for compaction test that were used are different which influence the readings of dry density and moisture content. For British Standard Light Test, the highest reading of dry density is 1.91 Mg/m^3 at 15% of geopolymer. Meanwhile, the highest dry density for British Standard Heavy Test is 2.07 Mg/m^3 at 15% of geopolymer.

Figure 4 and Figure 5 illustrates the comparison for dry density and moisture content for both types of compaction effort. These figures clearly show that the British Standard Heavy Test give better results of dry density and moisture content. The graph shows that with the increase of percentage of geopolymer, the dry density also increase and the value of moisture content are decrease. However, for soil mixture with 20% of geopolymer show a drop in dry density and increase in moisture content of the soil.

From the results, it can be said the maximum dry density are increase with the increase in percentage of geopolymer at certain point and decrease back when it reach it optimum value. It is proved byprevious researcher, Satheeshkumar and Ilampauthi [10]; Subhash *et al.* [11]; Rishi *et al.* [12]. Olaniyan *et al.* [13]

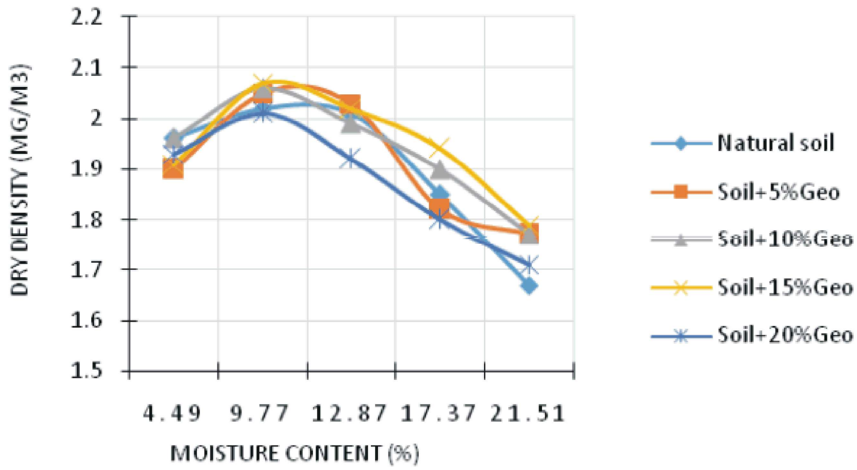

Fig. 2: Dry density and moisture content of natural laterite soil and laterite soil mix with different percentage of geopolymer for British Standard Heavy Test

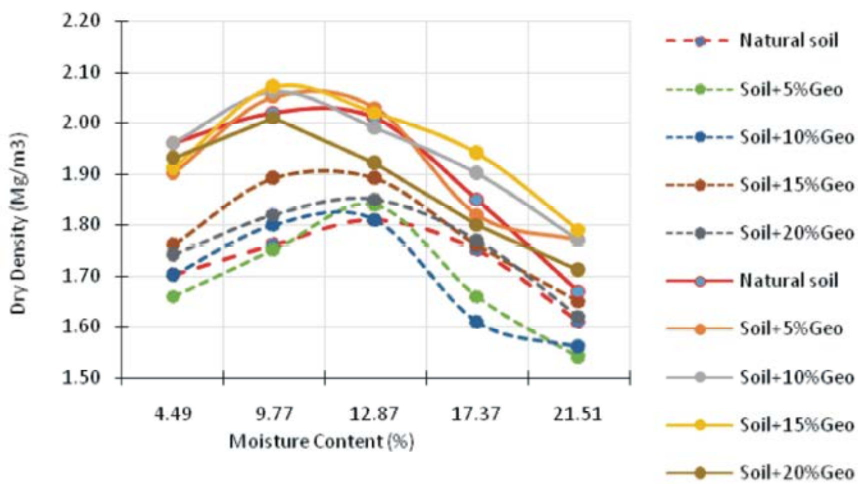

Fig. 3: Comparisonof dry density and moisture content between British Standard Light Test and British Standard Heavy Test

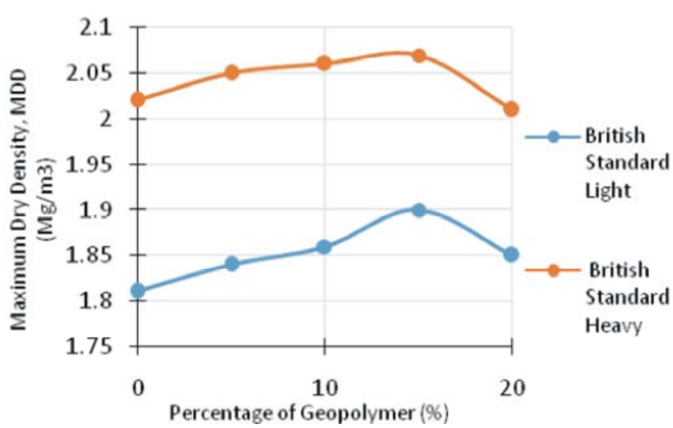

Fig. 4: Comparisonof Maximum Dry Density (MDD) between British Standard Light Test and British Standard Heavy Test

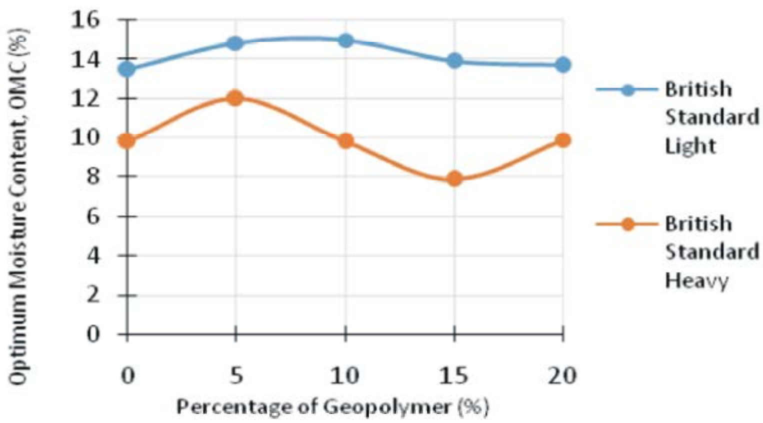

Fig. 5: Comparison of Optimum Moisture Content (OMC) between British Standard Light Test and British Standard Heavy Test

also proved in their findings that the geopolymer is one of the material that can improve the compaction parameter of the soil at certain percentage.The authors clarified that the addition of geopolymer to the soil increased the maximum dry density and reduced the optimum moisture content of the soil. Normally, an increase in the maximum dry density of soil indicates the soil improvement.

In addition, it is believe that 15% of geopolymer used in this laboratory experiment generate a higher value of maximum dry density for British Standard Heavy Test which is 2.07 Mg/m^3 and optimum moisture content 7.87% for soil specimen. The dry density of the specimens under 5%, 10% and 15% of geopolymer increased with increase in percentage of geopolymer. It is due to the bonding created by alkaline solution and the subsequent isomorphous substitution of Aluminium (*Al*) has indeed increased the packing between the grains. For 20% of geopolymer, the compaction parameter were decreased because both of compaction parameter already achieve its optimum value at 15% of geopolymer. The outcome of this study show that the soil mix with geopolymer give better value of dry density and moisture content compare to natural soil. Besides that, the application of geopolymer also help in improving compaction parameter because it is a material which can give a powerful compaction aid to the soil mixture and help increase the dry density of soil, increase the strength and reduce the moisture content of the soil. The laterite soil mix with 15% of geopolymer give the best value of dry density and thus give the high strength and low permeability of soil with the heavy and standard compaction effort. The geopolymer is one of the green technology material which can be used to improve the workability of laterite soil.

CONCLUSION

In a nutshell, the results revealed that the compaction effort and percentage of geopolymer give a big influence to change the compaction parameter of the soil. For this study, it is show that the British Standard Heavy Test gives high value of dry density compared to British Standard Light Test. Besides that, it is proved that the soil specimen with 15% of geopolymer with heavy compaction effort give better results which can drastically transform the value of dry density and moisture content of soil.

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