CALIFORNIA BEARIN[G R]ATIO OF KUANTAN CLAY SUBGRADE BY U[SING] [POLY]ETHYLENE (HDPE) AS STABILIZER

MOHD ZULFADLI BIN JUHARI

A report submitted in partial fulfillment of the
Requirements for the award of degree of
Bachelor of Civil Engineering

Faculty of Civil Engineering & Earth Resources
Universiti Malaysia Pahang

June 2012

ABSTRACT

Nowadays, the application of using high density polyethylene (HDPE) especially for storage and marketing of many liquids product are increased day by day. The design of these containers is usually for spot use with short life span and the consumer will discard them after used because of those we have to promote the utilizing of HDPE as polluted material as in road construction. The expecting municipal waste production in Malaysia will increase up to 300,000 tons near to 2020 which is from the human life. By this fact, the waste material from HDPE product such as plastic container also will be increase. That polluted waste can be as additives material in soil stabilization for road construction in Kuantan clay subgrade. This study proposed an assessment of the utilization of HDPE fibers as stabilizer of clay subgrade. The research will be conducted several of contents of HDPE fibers from waste plastic mixed with Kuantan clay as a samples. A series of California Bearing Ratio (CBR) test will carry out to the soil samples to estimates the optimum mixture design. The samples will set up by mixing soil samples with several of HDPE fibers and at optimum water content. By depending engineering properties of soils, it will stabilize the soft sub grade. The amount of HDPE tried were 3%, 6% and 9% by total weight. The proposed technique can be used to advantage in ground improvement and modification for highway project also in embankment project.

ABSTRAK

Pada masa kini, permohonan menggunakan polietilena berketumpatan tinggi (HDPE) terutama bagi penyimpanan dan pemasaran cecair produk banyak semakin meningkat hari demi hari. Reka bentuk bekas ini adalah biasanya untuk kegunaan serta merta dengan jangka hayat yang pendek dan menyebabkan pengguna akan membuang bekas –bekas tersebut selepas digunakan. Oleh sebab itu, kita perlu menggalakkan penggunaan bahan buangan daripada HDPE sebagai bahan binaan dalam pembinaan jalan raya. Pengeluaran sisa di Malaysia dijangkakan meningkat sehingga 300,000 tan berhampiran hingga tahun 2020. Dari fakta ini, bahan buangan daripada produk seperti bekas plastik HDPE juga akan meningkat. Bahan sisa tercemar ini boleh menjadi sebagai bahan tambahan dalam penstabilan tanah untuk pembinaan jalan raya pada bahagian subgred tanah liat di Kuantan. Kajian ini mencadangkan penilaian penggunaan gentian HDPE sebagai penstabil tanah liat pada bahagian subgred. Penyelidikan akan dijalankan ke atas beberapa kandungan gentian HDPE daripada sisa plastik yang bercampur dengan tanah liat Kuantan sebagai sampel. Satu siri Nisbah Galas California (CBR) ujian akan menjalankan kepada sampel tanah untuk menganggarkan reka bentuk campuran yang optimum. Sampel tanah akan dicampurkan dengan beberapa gentian HDPE dan pada kandungan air yang optimum. Kebergantungan kepada sifat kejuruteraan tanah, ia akan menstabilkan sudgrade lembut. Jumlah HDPE yang dicuba ialah 3%, 6% dan 9% oleh jumlah berat. Keputusan kajian menunjukkan bahawa penambahan 6% HDPE adalah peratusan yang terbaik. Teknik yang dicadangkan boleh digunakan untuk kelebihan dalam pembaikan tanah dan pengubahsuaian untuk projek lebuh raya juga dalam projek tambak.

TABLES OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

LL	-	Liquid Limit
PL	-	Plastic Limit
PI	-	Plasticity Index
Gs	-	Specific Gravity
γ_{max}	-	Maximum dry unit weight
kN	-	Kilo Newton
g	-	Gram
mm	-	Milimeter
°C	-	Degree of Celcius
µm	-	Micrometer

LIST OF ABBREVIATION

HDPE	-	High Density Polyethylene
CBR	-	California Bearing Ratio
PE	-	Polyethylene
AASHTO	-	American Association of State Highway and Transportation Officials
USCS	-	Unified Soil Classification System
ASTM	-	American Society for Testing Method
CBRI	-	California Bearing Ratio Index
UMP	-	Universiti Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 Research background

Nowadays, the application of using high density polyethylene (HDPE) especially for storage and marketing of many liquids product are increased day by day. The design of these containers is usually for spot use with short life span and the consumer will discard them after used because of those we have to promote the utilizing of HDPE as polluted material as in road construction.

The expecting municipal waste production in Malaysia will increase up to 300,000 tons near to 2020 which is from the human life. By this fact, the waste material from HDPE product such as plastic container also will be increase. That polluted waste can be as additives material in soil stabilization for road construction in Kuantan clay subgrade.

This study proposed an assessment of the utilization of HDPE fibers as stabilizer of clay subgrade. The research will be conducted several of contents of HDPE fibers from waste plastic mixed with Kuantan clay as a samples. A series of California Bearing Ratio (CBR) test will carry out to the soil samples to estimates the optimum mixture design. The samples will set up by mixing soil samples with several of HDPE fibers and at optimum water content. By depending engineering properties of soils and characteristic of additives, it will stabilize the soft sub grade. The amount of HDPE tried were 3%, 6% and 9% by total weight. The proposed technique can be used to advantage in ground improvement and modification for highway project also in embankment project.

1.2 Problem statement

The failures of subgrade on highway construction are largely reported in Pahang especially at East Coast Expressway and Kuantan-Pekan region. The soft sub grade in this region has been determined as a big problem in highway construction. The sub grade usually laid on soft clays may cause this matter and highway design can be classified as not economical because of the maintenance costs by this problem.

A wide range of reinforcement and many procedures have been used to improve soil performance and to increase the soil strength by incorporating a wide range stabilizing agents, additives and conditioners. Some of the reinforcement method is a costly and force some burden to the contractors. These a time to concern about to produce sustainable highway subgrades by using recycle and reused material as stabilizer which is more economical besides concern about the environmental friendly construction.

The increasing of using the plastic containers that made by high density polyethylene (HDPE) for storage and marketing of various liquid by people days by days. It will be harmful the environment in long term duration. It became worst because of increasing of world population which is can affect their life and health by polluted environment comes from the waste material such as HDPE. According to the data published by Department of Statistics of Malaysia, the Census 2010 revealed that the total population of Malaysia was 28.3 million, compared with 23.3 million in 2000. This gives an average annual population growth rate of 2.0 per cent for the period 2000-2010. The rate was lower compared to that of 2.6 per cent during 1991-2000. Meanwhile, the expected solid waste disposal in Malaysia will increase to 30,000 ton per day near 2020 and this is serious issues that must be concern.

As we know, HDPE can remain in the environment for hundreds or even thousands of years besides it design for spot use, having short life span and are being discarded immediately after use as their characteristics. This characteristic will affect the human life also will harmful to the environment. Some of the reused and recycling programs in Malaysia are not fully succeed may increase the municipal waste crisis.

The best solution for this problem is recycling them into other products. This means it can change from waste into other product that can give benefit to human life. It can be used in highway engineering or other engineering application for utilize them into benefits product

Therefore, this proposal proposed an assessment of the utilization of high density polyethylene (HDPE) fiber as stabilizer of soft sub grades material. The research will conduct various contents of HDPE fiber in 3%, 6% and 9% by total weight to the clays soils from East Coast Expressway as a sample. The compaction test and California Bearing Ratio (CBR) test will be applied in soil samples to estimate the optimum mixture design besides to demonstrate the potential of reclaimed HDPE pallets as a stabilizer for improving engineering performance of subgrade.

1.3 Objectives of the research

The main objectives of this study are:

1. To investigate the engineering properties of Kuantan soil.
2. To demonstrate the stabilized of Kuantan Clay by using high density polyethylene.
3. To determine the optimum content of stabilizer those give the maximum strength.

1.4 Scope of research

Scopes of this research include the following procedures:

i. Collect soil sample from Jalan Kuantan Pekang and high density polyethelene bottle from *Sigmaplus* Capital Sdn Bhd
ii. Engineering properties and strength test for original soil sample and stabilizer material.
iii. Design for stabilized soil and test the engineering properties and strength.
iv. Test result data coding and analyze follow the AASTHO and or Malaysian specification and support by computer and software.
v. Produce the report.

1.5 Expected result

The expected results from this study are:

1. Utilization of engineering properties of Kuantan Clay and stabilized of Kuantan Clay by using HDPE
2. Basic engineering data for developing research in ground stabilization.
3. The strength improvement in clay soil.

CHAPTER 2

LITERATURTE REVIEW

2.1 Introduction

The construction of building, roads, bridge and harbors on soft clays are facing the higher risk for settlement and stability problem. This has become main geotechnical problem in soft clay engineering (Brand & Brenner, 1981) stated that soft is defined as clay that has the shear strength less than 25kPa. Soft clay cause many problem to geotechnical engineers since it is highly compressible, high liquid limit and high plasticity.

2.2 Definition

2.2.1 Clay

According to Whitlow (2001) clay is define as soils particles having sizes below 2μm which can be determine at site by its feel that is slightly abrasive but not gritty and clay also feel greasy. Clays are flake shape microscopic particles of mica clay minerals and other minerals (Helwany, 2007). Clay is a common type of cohesive soil (Liu & Evett, 2005) which has small particle that cannot be separated by sieve analysis into size categorizes because there no practical sieve can be made with the so small opening. Clay is said as a submicroscopic mineral particle size of soil which has the fine texture when clay present in dominant proportions compare with silt and sand the soil is described as having a fine or heavy texture. Fine textured soils are plastic and sticky

when wet but hard and massive when dry. According to Tan (2005) the heavy texture used because they are very heavy and difficult to flow.

According to Singer & Munns (2006), clay is said to be surface active which means that much happen on their surface. Clay minerals cohere to each other and adhere to longer mineral particles. Their surface absorbs and holds water, organic compounds, plant nutrients ion and toxic ions.

2.3 Clay formation

Clay formation and translocation are processes that differentiate soils from rocks. Singer & Munns (2006), started that feldspar, mica, amphibole and pyroxene minerals are transformed into clays through process of hydrolysis, hydration and oxidation. As an example, in bitite mica, FE^{2+} can oxidize, K^{+} leaves the structure to maintain electrical neutrality and the structure is weakened. Next, soluble Ca^{2+}, Mg^{2+}, and Na^{+} in the soil solution replace the remaining biotite K^{+} to form vermiculite or montrimorillonite. All this may take place without any movement of mineral. Mica and other aluminosilicates can slowly dissolve into individual silica molecules and Al, Mg, K and Fe ions can recombine to form clay in the same location, where they recombine to form clay.

According to Brand & Brenne (1981) usually clay minerals are the product of rock weathering. The type and the amounts of clay minerals formed are affecting by climate, parent material, drainage pattern (topography) and vegetation. The most important affect is by the climate.

Young sediments such as soft clay must undergone little diagenese when it became to isostatic uplift or marine regression, whereas the sediments which are covered by big overburden, consolidate and dehydrate and make the particles become cemented. Further increase in temperature and pressure would lead to metamorphism, a process where the clay minerals are destroyed and new minerals such as mica and feldspar are formed. Tectonic pressure or volcanic activity can bring the metamorphism

material back to the surface where the first diagenese occur and by the weathering of the exposed rock, the formation of clay minerals start a new (Brand & Brenner, 1981).

2.4 Minerals of Clay Fraction

Singer & Munns (2006) stated that clay minerals have some common properties and important difference that are:

a. Clay minerals tend to form microscopic to submicroscopic crystal with large surface area. They are colloidal particle which are in range of 1ηm to 1μm in diameter.
b. Clays are platy or flaky microcrystal, reflecting their layered crystal structure. The shape and size explain clays slipperiness and plasticity when wet and tendency of clay particles to stack and stick together to coat larger particles and to line pores. Plasticity describes the ability of clay to be molded into forms that remain their shape.
c. All clays absorb or lose water on their surface when the water content changes. Some clay allows water into interlayer of their molecule structure. When water is absorbed, clays expand as the water leaves the space.

Table 2.1: Typical range of index properties of some common clay minerals (Shroff & Shah, 2003)

Clay Minerals	Liquid Limit Range	PI range
Kaolinite	40-60	10-25
Illite	80-120	50-70
Sodium montrimollite	700	650
Other montrimollite	300-650	200-250
Granular soils	20 or less	0

2.5 Clays as Problematic Soil

In the entire world, there are many types of problematic soils such as swelling and shrinkage clay, collapsible soils, quick sands or clay, frozen soil and peat. The consequence by building the structure in such soils can result in considerable financial loss (Bell & Culshaw, 2001). Clay that contains high montmorillinite becomes a dangerous and problematic soil. It is found in tunnels or road cut subgrade that can expandable nature, can lead to serious slope or wall failures and pavement cracking and pavement structure failure stated by Achmad (2011). Table 3 shows the chemical element for Kuantan Clay.

Table 2.2: Engineering properties of clay soil (Achmad et al, 2011)

COUNTRY	CODE NO.	DESCRIPTION	CLASSIFICATION	PASSING SIEVE NO (%)			LL	PI	GS	SL (%)
				10	40	200				
MALAYSIA	K/2	White clayey silt	A-7-6	95.98	85.92	33.77	63.50	37.80	2.67	7.86
	K/4	Yellow brownish clay	A-7-6	92.80	83.12	44.63	30.50	11.56	2.65	3.57
	K/6	Yellow grayish clay	A-7-5	78.42	60.17	52.87	51.50	14.50	2.66	9.00
	K/8	Brown laterite clay	A-7-5	82.52	57.40	52.14	53.50	14.83	2.78	9.36
	K/24	Gray whiteish silty clay	A-7-6	85.73	52.62	36.68	47.50	12.58	2.65	10.00
	K/25	Gray blackish clay	A-7-6	85.73	58.03	44.44	40.00	12.58	2.64	8.57
INDONESIA	Plg/1	Brown laterite clay	A-7-5	93.35	76.10	44.20	53.40	27.90	2.60	29.00
	Plg/2	Brown clayey silt	A-7-5	98.21	90.60	78.77	54.00	26.50	2.60	33.00
	Sky/1	Red whiteish clayey silt	A-7-5	99.97	99.22	69.98	61.00	30.62	2.62	11.00
	Sky/2	Brown clayey silt	A-7-5	90.33	72.16	56.12	52.00	26.50	2.58	24.00
	Sky/3	Brown clayey silt	A-7-5	98.73	98.14	58.51	59.00	30.00	2.61	44.00
	BA/1	Red laterite clay	A-7-5	90.63	88.75	81.83	70.90	43.35	2.65	87.00

Kuantan clay was high plasticity. These soils cannot be used as embankment material or have to avoid. If the used of soils cannot reasonably avoided, such material shall be used only on bottom portion of embankment. The engineering of problematic clays like this could be improved by stabilizer.

Table 2.3: Chemical element for Kuantan clay (Achmad et al, 2011)

NO	ELEMENT	S2	S4	S6	S8	S24	S25
		WEIGHT (%)	WEIGHT (%)	WEIGHT (%)	WEIGHT (%)	WEIGHT (%)	WEIGHT (%)
1	C $CaCO_3$		5.05	8.42	6.05	7.48	10.25
2	O SiO_2	54.21	58.97	56.67	53.15	59.83	58.98
3	Al Al_2O_3	6.82	12.81	13.07	14.04	11.17	8.51
4	Si SiO_2	34.33	18.99	11.99	6.07	18.82	16.13
5	S FeS_2						2.24
6	K MAD	2.23	1.16	0.81		0.92	0.86
7	Ti Ti			0.43	2.37	0.58	
8	Fe Fe	2.41	3.02	8.62	18.32	1.2	3.02

The chemical element of Kuantan clay soil tested by integrated electron microscope and energy-disperse x-ray Spectroscopy (SEM-EDS) has been report (Achmad et al, 2011).

2.6 Essentials of soil improvement

Soil reinforcement is defined as a technique to improve the engineering characteristics of soil. On the other hand, soil improvement or reinforcement consists of incorporating certain materials with some desired properties within other material which lack those properties (Jones.M, 1999). This because, soil can often regarded as a combination of four basic types which is gravel, sand clay and silt. It generally has low tensile and shear strength and its characteristics may depend strongly on the environment condition such as dry versus wet (Ling.I et all, 2003). Therefore, soil reinforcement is defined as a technique to improve the engineering characteristics of soil in order to develop the parameters such as shear strength, compressibility, density; and hydraulic conductivity (S.Kazemian et all, 2010). Usually, reinforced earth is a composite material consisting of alternating layers of compacted backfill and man-made reinforcing material (Ola.A, 1989).

2.7 Fibers and soil improvement

As we know, soil reinforcement is a procedure where natural or synthesized additives are used to improve the properties of soils which is used to solve a problematic soils (H.Syyed, 2010). There have a various techniques of soil reinforcement can classify into a number of categories with difference point view as shown in Fig. 1 (H.Syyed, 2010). This figure emphasized that short fiber soil composites have recently attracted increasing attention in geotechnical engineering and studies on mechanical behavior of short fiber soil composite are comparatively new when compared to other research fields (L.Michalowiski, 1996).

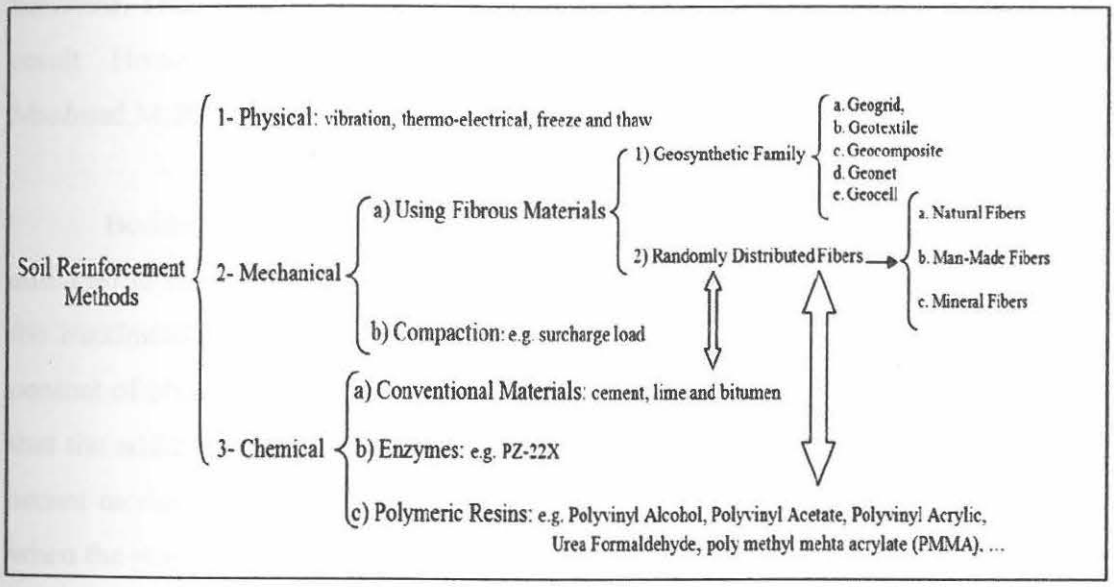

Figure 2.1: Different procedures of soil reinforcement

The standard fiber reinforced soil can be defined as a soil mass that contains randomly distributed, discrete elements such as fibers which provide an improvement in the mechanical behavior of the composite (Li.C, 2005). As reported (R.Jamshidi et all, 2010), shear stresses in the soil mobilize tensile resistance in fibers, which in turn imparts greater strength to the soil. This is because, fiber reinforced soil behaves as a composite material in which fibers of relatively high tensile strength are embedded in a matrix of soil.

2.8 High Density Polyethylene Fibers

There many report that polyethylene (PE) fibers or strips has been used in soil reinforcement in investigation to a limited extent (Yetimoglu.T, 2005). Furthermore, it has been reported that the presence of small fraction of high density PE (HDPE) fibers can increase the fracture energy of soil (K.Choudhary et all, 2010). Sobhan and Mashand (2002) demonstrated the importance of using toughness as a measure of performance. These studies showed that increases in tensile strength with added HDPE strips were not realized but large increases in toughness resulting from increased strain capacity was observed. With increasing toughness, much of the expected performance benefits due to fiber inclusion are in the post-peak load portion of the stress–strain behavior. Thus, as the fibers develop tension, an improved stress–strain response is the result. However, improvements in fatigue behavior were not noted (K.Sobhan, Mashnad.M.2002)

Besides that, Kim et al. used PE waste fishing net (0%, 0.25%, 0.5%, 0.75%, and 1%) to reinforce lightweight soil derived from dredging process. They found that the maximum increase in compressive strength was obtained for a waste fishing net content of about 0.25% (Kim.T,Kim.J,Lee.G. 2008) . Choudhary et al (2010). reported that the addition of reclaimed HDPE strips to local sand increases the CBR value and secant modulus. The maximum improvement in CBR and secant modulus is obtained when the strip content is 4% with the aspect ratio of 3, approximately three times that of an unreinforced system. As well, base course thickness can be significantly reduced if HDPE strip reinforced sand is used as sub-grade material in pavement engineering (Choudhary.K et all, 2010).

As it can be seen environmental purposes are the main reason of using PE fibers and/or strips in geotechnical engineering to landfill the waste PE-based materials.

2.9 California Bearing Ratio (CBR) Improvement

Soil with fiber composites are been found effective in improving CBR value as reported in literature (Hoover. J.M et all, 1982). These studies will indicate that stress-strain properties of samples are function of HDPE fiber content and aspect ratio. By using of high density polyethylene fiber improved peak and ultimate strength of both cemented and un-cemented soil (Bueno.B & de Souza, 1997). Besides that, strength and load bearing capacity of soil was increase when the soil is stabilized mechanically with short thin plastic strips of different length and content (Rao.G.V et all 2004). The feasibility of reinforcing soil with strips of reclaimed high density polyethylene has also been investigated to a limited extent (Dutta.R.K et all 2007). It has been also reported that the presence of a small fraction of HDPE fiber can increase the fracture energy of the soil. Although, a few studies on the subject of engineering behavior of HDPE reinforced soil as described earlier are available in literature but a detailed study pertaining to its use in real life problems is still quite meager. In view of the above limited studies, present study has been taken up with special reference to its feasibility for application in embankment/road construction.

The basic construction material for road and highway is soil which is support the sub base and base in the pavement design. The unsuitable of existing soil at a particular location may not be suitable for the construction due to poor bearing capacity and higher compressibility or even sometimes excessive swelling in case of expansive soils. In developing countries, there many method and widely used for soil stabilization for unsuitable soil in pavement construction. This is because the soil stabilization method which is used of locally available materials will lead to more economical projects. The application of using the recycling material as stabilizer of soil, report that it can reduces the cost and improve the soil strength (A.K. Choudhary, J.N. Jha and K.S. Gill).

2.10 Kuantan Clay Soil

Clay soil can be stabilized by addition small percentage of stabilizer such high density polyethelene (HDPE). Report that in last research, the objective of the soil stabilization is improving engineering properties quality and in increases the soil

strength (Fauzi. Achmad, 2011). The engineering properties and strength properties of Kuantan clay and Kuantan clay stabilized with stabilizer have to utilize to improve the road structure quality, decrease thickness and decrease cost of construction in Kuantan state significantly. One of the solutions is to improve the characteristics at site and make soil capable of carrying load and to increase the shear strength decrease the compressibility of the soil. Soil Stabilization was one of the well-known methods in ground improvement.

The engineering properties quality improvement and increase of strength reported by many researchers by their research. The addition of lime in certain percentage increased in optimum water content and decreases their maximum dry density, as well as enhanced California Bearing Ratio (CBR) (F.G. Bell 1996). Lime stabilization of Kuantan Clay creates a number of important engineering properties in soils such as improved workability, providing a working platform for subsequent construction, reducing plasticity to meet specifications, conditioning the soil for further treatment but until decreased CBR when content of lime more than 4 percentage. (Fauzi. Achmad, 2011).

2.11 Sampling

Sampling can refer to the taking of soil or rock from bored holes (Liu & Evett, 2005). Besides that, Brand & Brenner (1981) state that samplings are the samples are used for soils identification and determination of soil properties and it is required for almost every investigation. Depending of type of soils, the choice of the sampler type and sampling techniques can be obtained and it necessary for obtaining undisturbed samples

It is necessary to collect the sample of soil that have exactly the same as it was exist beneath the ground if the sample will be used for determination of certain properties of soil such as strength, compressibility and permeability. This type of sampling method known as undisturbed sample which is obtain by pushing a thin tube into the soil thereby trapping the sample inside the tube and then remove the tube and

sample intact. The thin tube should be sealed at the end with paraffin wax immediately after the sample has been taken to the ground surface.

The disturbed sample is the sample brought by the auger boring to the ground surface. It is different from undisturbed sample because disturbed sample can change of their characteristic. This type of sample should be kept in airtight container such as plastic bag or airtight jar and should be properly labeled with location, date, boreholes number, sampling depth and sample number. According to Brand and Brenner (1981), disturbed samples is used for particle size analysis, determination of liquid limit and plastic limit, moisture content and any other test that is suitable and necessary to be done.

2.11.1 Sample Quality

According to Craig (2004), the sampling method used should be related to quality of sample required. Furthermore, clays are extremely sensitive to any sampling disturbance, the effects being more pronounced in clays of low plasticity than those of high plasticity. Therefore, in other to preserve sample quality, special care is required in handling, transportation and storage of samples prior to testing.