SHEAR STRENGTH OF FIBRE REINFORCED CLAY SOIL

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ABSTRACT

Improving the soil condition in order to provide a greater advantage in supporting the structure above ground has always been the major interest for geotechnical engineer or specialist. An effective improvement method can guarantee a greater development potential for the country and hence bring numerous benefits to the nation people. Among all the types of soil existing on our country's ground, clayey soil is one of them. Unfortunately, clay soil is known to have low supporting strength compared to others type of soil in the construction industry. Hence, this project is to investigate the shear strength behaviour of medium plasticity clayey soil responding on the influential of fibre percentage. The fibre was prepared by cutting the fishing threads into 1-2mm in length and the soil sample was collected around UMP. A range of fibres percentages were added corresponding with the soil mass in a random distribution manner and the shear strength parameters were determined using unconsolidated undrained triaxial compression test method. The result proved that the fibre reinforced clayey soil has a relatively higher shear strength compared with the unreinforced clayey soil. The increment of shear strength is proved to be 49% for the fibre percentage of 0.4 which is the optimum fibre content percentage where it gives the highest increment of shear strength. Anyhow, the increment percentage is relatively low compared with the published data of similar research.

ABSTRAK

Untuk memperbaiki keadaan tanah supaya memberikan kelebihan besar dalam menyokong struktur bina di atas tanah telah dijadikan fokus utama bagi jurutera atau pakar geoteknikal. Kaedah memperbaiki yang berkesan dapat menjaminkan potensi pemabangunan negera yang besar dan dengan itu membawa maafaat yang banyak kepada rakyat negara. Antara jenis-jenis tanah yang ada atas tanah negera kita, tanih liat adalah salah satu jenis yang biasa dinampak. Malangnya, tanah liat diketahui mempunyai kekuatan rendah untuk menyokong struktur bina berbanding dengan jenis tanah yang lain dalam industri pembinaan. Oleh itu, projek ini adalah untuk menyiasat sifat kekuatan ricih untuk tanah liat mempunyai keplastikan serdahana bertindak balas terhadap pengaruhi peratusan serat. Serat disediakan dengan memotong benang pancing kepada 1-2mm panjang dan sampel tanah dikumpulkan di sekitar UMP. Beberapa peratusan serat ditambah sepadan dengan jisim tanah dengan cara taburan rawak dan parameter kekuatan ricih ditentukan dengan menggunakan tanah liat yang taktersalir dan tidak disatukan dalam ujian mampatan tiga paksi. Keputusan project ini membuktikan bahawa tambahan serat berjaya mengukuhkan tanih liat dengan mepertingkatkan kekuatan ricih kepada 49% bagi peratusan serat sebanyak 0.4% di mana 0.4% juga merupakan peratusan kandung serat yang optimum sebab ia memberikan kenaikan kekuatan rich yang paling banyak. Walau bagaimanapun, peratusan kenaikan agak rendah berbanding dengan data penyelidikan yang serupa.

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LIST OF SYMBOLS

c	Cohesion of soil
φ	Internal friction angle of soil
σ	Normal stress
τ	Shear stress
N	Number of blow
ρ	Density
w	Water content in percentage divided by 100
G_s	Specific gravity

LIST OF ABBREVIATION

UMP	Universiti Malaysia Pahang
BS	British Standard
CPT	Cone penetration test
UU	Unconsolidated undrained
UCS	Unconfined compressive strength
POF	Palm oil fibre
LL	Liquid limit
PL	Plastic limit
PI	Plasticity Index
USCS	Unified soil classification system

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Different type of soil deposition is found around Malaysia. One of the common types will be the deposits of soft clay. Soft clay are usually highly compressible and having very low shear strength. As a result for this, problems are encountered when civil works are carried out on this soft clay deposit. Somehow constructing buildings on the soft clay soil is inevitable due to the rapid development of certain regions of Malaysia, for example Kuala Lumpur. The demand of civil works is gradually increasing due to the rapid growth of populations as well as the mega investment construction project jointed internationally. Hence, various type of soil improvement method is to be investigated and studied during recent years in order to solve this problem.

Some of the traditional method used for soil improvement is removal and replacement, preloading, in-situ densification etc. Reinforcement of soil using various types of materials has become popular recent years. Many studies are undergoing to investigate how the reinforcement materials can affect the shear strength of the soil. Materials used ranged from recycled material like plastic fibre strip, palm oil fibre, fly ash; to commercial manufactured fibre material like geotextile fibre.

As a matter of fact, the roots of soil fibre reinforcing can be traced in history of human kind to thousands of years ago. The remainder of houses built with thatch, plant roots and other natural fibres as reinforcing elements to prevent cracking in masonry materials proves this historical fact. Such buildings can still be found in some rural places ,where people use low strength fibre-like materials like straw to reinforce low strength masonry walls. In this study, fibre reinforcement will be discussed and analyzed extensively and plastic fibre will be used as the reinforcement material for the clay soil.

1.2 OBJECTIVES

a) To study the shear strength behaviour of the fibre reinforced medium plasticity clayey soil.
b) To study the relationship between the cohesion values, c and internal friction angles, φ with the fibre content for a fibre reinforced medium plasticity clayey soil.
c) To study the failure deviator stress of fibre reinforced medium plasticity clayey soil.

1.3 SCOPE OF STUDY

The study focuses on investigating the increase of the shear strength of clayey soil after the fibre reinforcement. The soil sample is collected around the UMP campus whereas the fibre strip is cut from fishing thread. The triaxial compression test in accordance to BS 1377 Part 7 is conducted to determine the shear strength parameters of the sample soil. Two experiments are conducted, one with the soil sample unreinforced, and the other soil sample with fibre reinforcement. Four set of fibre content percentage will be prepared which is 0.2, 0.4, 0.6 and 0.8. All the soil samples are controlled with constant optimum moisture content and density. These 2 sets of results will be compared.

1.4 PROBLEM STATEMENT

Commonly, clay soil is known to have low undrained shear strength and in fact it takes a great period of time in order to drain the clay soil and obtain a higher value of shear strength. Hence, all sorts of method of improvement of clay soil need to be studied and investigated to satisfy both the cost and time effectiveness factors during the soil improvement process.

As a matter of fact, numerous studies have been done in investigating method on how to improve the shear strength behaviour of clayey soil. Recent research shows that most of the researchers are focusing on the fibre reinforced method where different sort of material can be used. Therefore, this study will be adapted to clay soil sample in a specified location which is around UMP campus and the shear strength behaviour will be studied and evaluated.

1.5 SIGNIFICANCE OF STUDY

Land available for construction building structure is getting lesser and lesser especially in the fast pace growing townships and regions in Malaysia. Land development is crucial in bring good economical impact in the country as well as foreign investment.

An effective way to improve the soil condition can definitely solve this problem of limited land for development. Using fibre as reinforcing material has been proved to be a promising method, hence, by exploring different alternatives of methodology, will help in finding a solution which brings benefits to geotechnical and as well as structural design.

CHAPTER 2

LITERATURE REVIEW

2.1 SHEAR STRENGTH OF SOIL

In very simple terms, the strength of soil is the maximum shear stress it can sustain, or the shear stress acting on a shear slip surface along which it is failing. Thus, structural strength is primarily a function of shear strength. Shear strength in soils is the resistance to movement between particles due to physical bonds from Particle interlocking, atoms sharing electrons at surface contact points and chemical bonds such as crystallized calcium carbonate. (Atkinson, Davidson, Springman, 2000) Figure 2.3 illustrates the failure plane of elemental soil mass due to normal and shear stress.

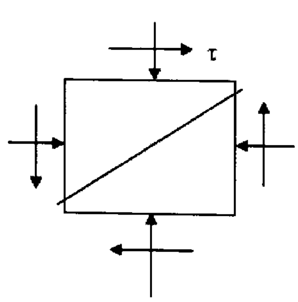

Figure 2.1: Failure plane of a soil mass due to normal and shear stress

Source: Atkinson, Davidson, Springman, 2000

In a more refining term, shear strength is considered to result from difference between the inter-particle forces of attraction and repulsion, with inter-particle attraction due to mainly to van der Waals forces and repulsion to the charge on the clay mineral surface. (Warkentin, 2000) Warkentin (2000) in his research showed that differences in inter-particles forces in the clay-water-ion system were reflected in differences in shear strength. Inter-particles forces may influence strength directly. Figure 2.4 shows the interacting clay particles with inter-particle repulsion resisting particle arrangement during development of failure plane.

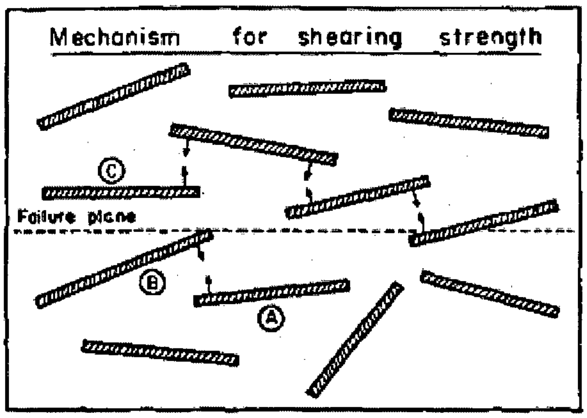

Figure 2.2: Schematic diagram of interacting clay particles

Source: Warkentin, 2000

In situ strength of soil is equally important for geotechnical engineering practice. The cone penetration test (CPT) is commonly used to determine the subsurface stratigraphy and estimate geotechnical parameters for design. Cone penetration test date can be empirically correlated to undrained shear strength determined from the triaxial compression tests. To calculate the undrained shear strength from CPT data, the correlation equations utilized must be corrected for pore water pressures. The pore water pressure used in these correlation equations is usually measured by the cone penetrometer. (Karakouzion, 2002)

Karakouzion (2002) had presented the field measurements of undrained shear strength in unconsolidated marine clay. The triaxial test result was to be compared with the vane shear test result and the vane shear test result was proceeded to be compared with the CPT result and hence, the research concluded that depending on the chosen value of N, the undrained shear strength has increased slightly or has approximately doubled based on the investigation of CPT to in situ shear measurements. Hence, it is critical to determine the appropriate N value for a particular site if CPT values will be used in determining the in-situ strength.

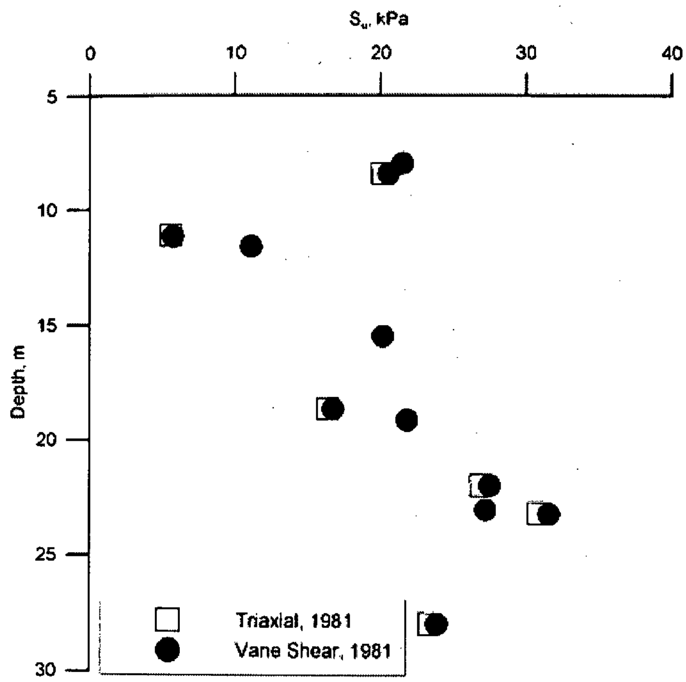

Figure 2.3: Undrained shear strength from the vane shear test and triaxial test (UU) for west dike

Source: Karakouzion, 2002

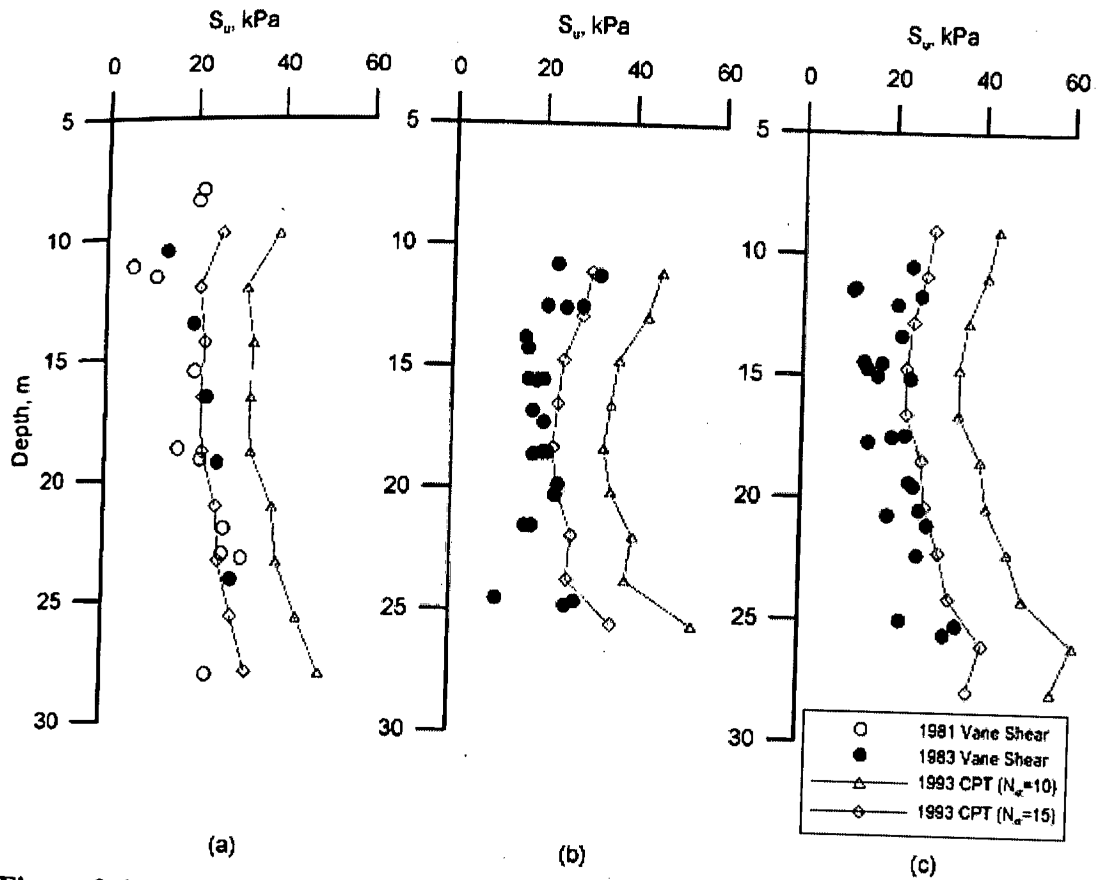

Figure 2.4: Vane shear test data and corrected 1993 CPT data for (a) west, (b) east (c) and north dike

Source: Karakouzion, 2002

2.2 SHEAR STRENGTH OF FIBRE REINFORCED CLAY

Along the years, so many researchers have been trying to discover a perfect solution for reinforcing the clay soil. Each and every of them were using different approach and methodology in their research. As a matter of fact, using fibre to reinforce clay soil has been proven to be effective in increasing the shear strength of the clay soil. Pashazadeh (2011) shows us that by using polyethylene fibres, the shear stress has been increased at fibre content of 3%. He also stated that the highest shear resistance occur at optimum moisture content while the least resistance occur at the saturated state. Figure 2.5 illustrates the result for Pashazadeh (2011)'s research. Meanwhile, Freilich (2011) had done a research on studying the effective shear strength of fibre reinforced clays using polypropylene. Figure 2.5 illustrates the stress path for fibre reinforced and unreinforced clays specimens from ICU triaxial testing.

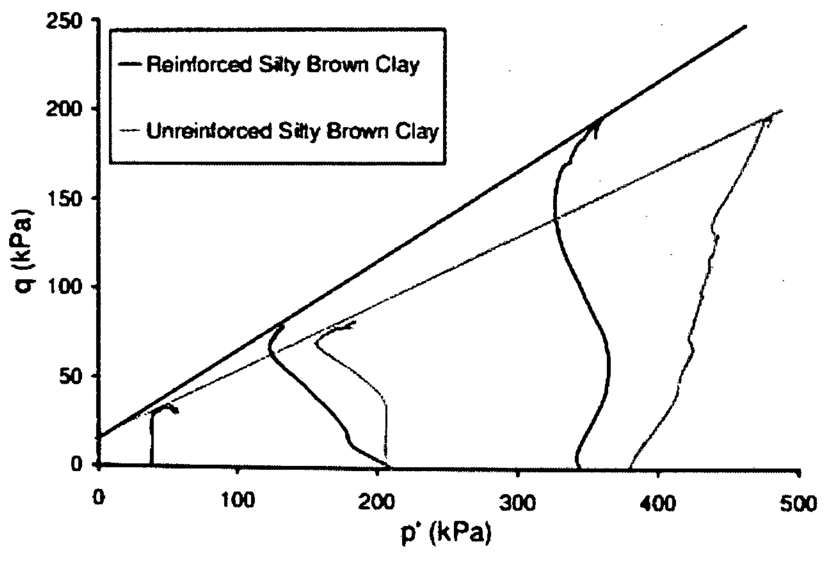

Figure 2.5 Stress path for fibre reinforced and unreinforced clays specimens

Source: Pashazadeh, 2011

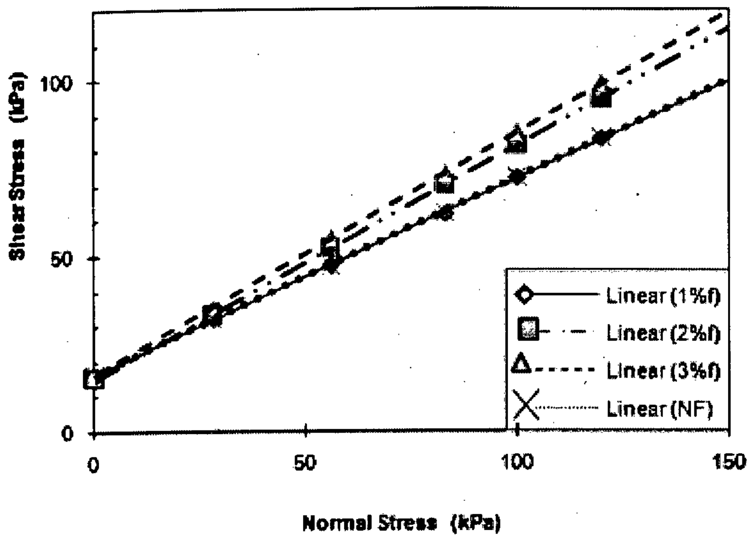

Figure 2.6 Changes in shear stress on the vertical stress with different weight percentages

Source: Pashazadeh, 2011

As for research done in Turkey, scrap tire rubber were cut and used by Akbulut, Arasan, and Kalkan (2007) as the reinforcing material of clayey soil. The fibre was randomly oriented in the soil sample and fibre of 10mm gives the optimum increment of unconfined compressive strength at 0.2% of polypropylene content. Figure 2.7 illustrates that fibre length of 10mm gives the highest UCS value.

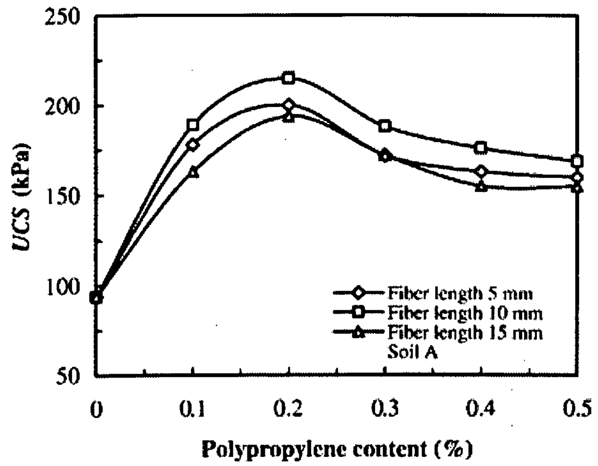

Figure 2.7: Fibre length of 10mm gives the highest UCS value.

Source: Akbulut, Arasan, and Kalkan, 2007

The variation of fibre length and types of fibre had been tested, and the result is shown as below. From the result shown, fibre length in 10mm in 0.2% seemed to be contributing a highest value of cohesion but not for the case of angle of friction. In general, tire rubber and synthetic fibres increased the cohesion values in a constant fibre content of 0.2%. The maximum cohesion values were observed for 10-mm long fibres.

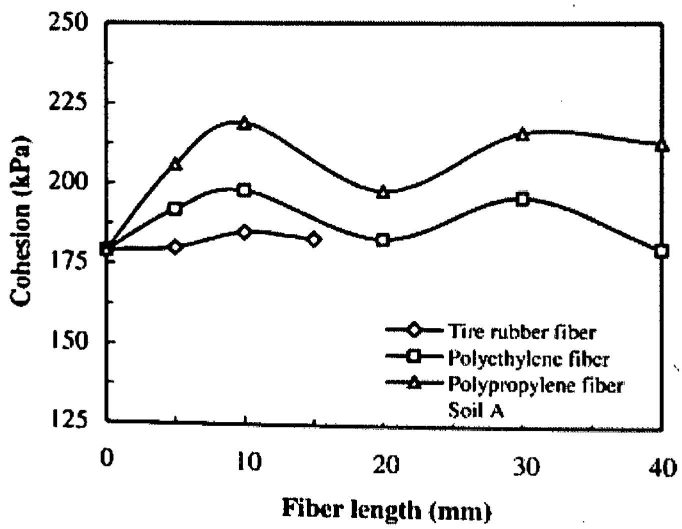

Figure 2.8: 0.2% of 10mm Polypropylene fibre gives the highest cohesion

Source: Akbulut, Arasan, and Kalkan, 2007

Using natural fibre instead in research had been carried out by researchers in Malaysia. Jamellodin (2010) shows that palm oil fibre can significantly increase the shear strength of the soft soil. The fibre percentages of 0.75 give the highest value of shear strength increment. This statement has been proven by another researcher; Noor (2010) in Malaysia who had done the similar research. Table 2.1 shows the result obtained by Jamellodin (2010) in his research.

From the table 2.1, we can see that the shear stresses of fibre reinforced soil are improved due to the addition of POF. The shear stresses also increased with increase confining pressure. But beyond 0.75% POF content, the shear stress reduces with increase in fibre content. When the percentage of POF content is increased, the density of the soil fibre mass in reduced and thus may be the reason for this reduction. (Jamellodin, 2010)

Table 2.1: Shear parameters of the reinforced soil (Jamellodin , 2010)

No.	Fibre content (%)	Cohesion (k/m^2)	Angle of Internal Friction (degrees)
1	0	21	18
2	0.25	43	17
3	0.50	48	13
4	0.75	79	16
5	1.00	35	12

Using natural fibres to reinforce soil has increasing in popularity due to the reasons of their strength, weight, durability and low cost. Ghavami (1998) had conducted a research on using two types of natural fibres, i.e., sisal fibres and coconut fibres. He had concluded that the inclusion of natural fibres in the soil matrix was significantly increased the compressive strength. He suggested that the bond between soil matrix and fibre should be further studied.

Besides using natural fibres, waste materials are popular material used as fibre to reinforce soil as well. Not to mention, these waste materials, for example, fly ash has been commonly used in reinforcing concrete and has been proved to significantly increase the compressive strength. Jongpradist, 2010 had concluded in the research that with suitable amount of cement content in cement-admixtured clay, fly ash can be successfully added into soil matrix and enhance both the physical characteristics and strength. The strength of cement-fly ash admixed clay at high water content increased with increasing amount of cementitious material content and duration of the curing time and decreased with increasing water content. The efficiency of fly ash depended on the portion of cement, disposed fly ash, and water content in mixtures.

Table 2.2: Summary of previous research regards the fibre reinforced clayey soil

Type of Fibre	Type of Clay Soil	Publisher/ Author (Year of Published, Location)
Fly ash (obtained from thermal power plant)	Local soft soil LL=44, PL=24	Ghosh, A. Utpal Dey (2009, India)
Coconut fibre	Region local soil LL=24	Khosrow Ghavami, Romildo D. Toledo Filho, Normando P. Barbosac (1998, Brazil)
Oil Palm fibre	Soft soil	Zalipah Jamellodin, Zaihasra Abu Talib, Roslan Kolop & Nurazuwa Md Noor (2010, Malaysia)
Very high lime fly ash	High plasticity clay soil LL=71, PL=30	Alper Sezer,Gozde Inan, H. RecepYılmaz, Kambiz Ramyar (2004, Turkey)
Polyester fibre	Highly compressible clayey soil	Kalpana Vinesh Maheshwari (2011, Surat)

Polyethylene	LL= 58 PL= 23 PI = 37	Akbar Pashazadeh, Mahmood Ghazavi, Morteza Chekaniazar (2011, Iran)
Surplus Carpet Fibres	LL=29 PL=12 PI=17	M. Mirzababaei, M. Miraftab, P. McMahon, M. Mohamed (2009, United Kingdom)

2.3 Others Clay Soil Improvement Method

There are many others method of clay soil improvement has been conducted by researchers around the globe besides using fibre. The purpose of improvement isn't to be restrained involving only the shear strength behaviour of clay soil but some others property instead for example swelling of clay soil. A numbers of studies had been conducted by using stabilizers to improve the swelling of expansive clay soil, for example, lime, cement and fly ash. However, the utilization of gypsum as stabilizing agent was becoming the study objective for Yilmaz and Civelekoglu (2009) in Turkey. They studied the performance of gypsum as stabilizing agent for treatment of expansive clay soil by means of swell potential and strength. Gypsum is proved to be a good stabilizing agent for expansive swelling clay soil though lime can perform well as stabilizing agent but gypsum appears to be a 3 times cheaper product compared to lime. (Yilmaz & Civelekoglu, 2009)

Besides the method mentioned above, another method was found to be effective in improving expansive clay soil is by using cationic-electrokinetic for delivering a homogenously stabilizing agents in the soil. Electrokinetic process can be effective in transferring the stabilizing ions into even the most low permeability soil. The result shows that the potassium ion can greatly improve the soil properties due to the linkage provided by the ions itself.

The K^+ stabilized soil by the electrokinetic process brought drastic reduction in the Plasticity Index from 40 for the natural soil to 8. Not only that, the K^+ stabilized soil also brought drastic reduction in the percent free swell from 14% for the natural soil to 0.4%. (Abdullah & Al-Abadi, 2009)

Another research was found to be conducted in Taiwan by enhancing the electrosmosis method by injection of saline solution in improving the shear strength behaviour of silt clay soil. The result stated that merely by electrosmosis process, the shear strength of silt clay is improved by 1.25 times compared to natrual shear strength while injection of saline solution brought a 5 times increment of shear strength compared to electrosmosis increment shear strength value. Hence, a better quality of electroosmotic improvement can be enhanced by injecting solutions of higher valence, concentration and applied higher electric potential. (Chang, Shao & Wang, 2008)