e-ISSN: 2289-6589

INVESTIGATION ON THE POTENTIAL USE OF PLASTIC FIBRE TO IMPROVE CONSOLIDATION BEHAVIOUR IN EARTHWORK APPLICATIONS

***Nor Hafizah Hanis Abdullah, Muhammad Syahiran Wazini Izani, Roziah Keria, Adhilla Ainun Musir**

Faculty of Civil Engineering,
Universiti Teknologi MARA Cawangan Pulau Pinang,
13500 Permatang Pauh, Pulau Pinang, Malaysia

*Corresponding author's email: nhhanis@ppinang.uitm.edu.my

Submission date: 30 July 2018 Accepted date: 30 August 2018 Published date:30 March 2019

Abstract

Problems of excessive settlement due to consolidation process in compressible soil is inevitable at some construction sites in Malaysia. For earthworks, soil with good bearing capacity and strength is required to support the structural loads. Sometimes, locally available soil is not eligible for construction works. Soil improvement method is needed to make sure the stability and control of soil settlement of the embankment. In this paper, an experimental work has been carried out to investigate the potential of plastic fibre to improve soil consolidation behaviour. The soil-plastic fibre (as reinforcement material) is compacted at optimum moisture content with different percentage of the plastic fibre i.e. 0.25%, 0.5%, 1% and 2%. 1D-consolidation oedometer test was carried out for this purpose. After the laboratory study was conducted, the coefficient of volume change (mv) and compression index (Cc) increase from 0% up to 1% and only shows sign of reduction at 2% of the solid plastic fibre. As for the coefficient of consolidation (C_v), the value increase with the increment of the percentage of plastic fibre used. Meanwhile, the time rate of consolidation (t_{90}) of the soil reduces as the percentage of the plastic fibre increases. Therefore, the plastic fibre as soil reinforcement to reduce settlement has the potential to be used given that the amount of plastic fibre is more than 2%.

Keywords: Settlement, consolidation, plastic fibre, earthworks

1.0 INTRODUCTION

Compressible soil is defined as low strength and susceptible to excessive settlement. Soil improvement or interchangeable use with soil reinforcement is usually carried out by using various available methods and materials that can resist tensile stresses, in which soil-fibre friction occurs at the contact surface. A lot of soil improvement techniques have been conducted using fibrous material such as plastic, polypropylene, glass, natural fibre and others. Past researchers agree that using fibres can reinforce problematic soil.

While consolidation behaviour of reinforced soil has not been intensely explored compared to the strength factor, there is a need to investigate the consolidation characteristics of stabilized soil due to the information gap in this field. Previous study reported that plastic-reinforced soil could improve the consolidation behaviour of compressible soil using plastic strip of various sizes obtained from plastic bottle wastes (Laskar & Pal, 2013). Plastic-fibre could also improve the strength of the soil (Muntohar, Widianti, Hartono

& Diana, 2013; Kalliyath, Joy, Paul & Vadakkel, 2016; Patle, Burike, Madavi,& Raut, 2017). More information is required to confirm the suitability of plastic-fibre with uniform size and thickness to improve consolidation characteristics.

Therefore, this study aims to investigate the potential use of plastic-fibre to enhance consolidation characteristics by using 1D Consolidation Oedometer Test. The outcomes from this study would contribute to the literature knowledge in soil improvement techniques. In addition, utilization of plastic-fibre could minimise the cost incurred because it can be obtained from plastic wastes. Even though it is a non-biodegradable product, it could not make harmful threat to the environment compared to other chemical treatments, since only less than 5% of this material is needed to increase the soil strength (Mallikarjuna & Mani, 2016).

2.0 LITERATURE STUDY

Generally, there are three methods available to stabilise soil, i.e. physical, mechanical and chemical. Physical method is practical to be used and requires high level technology. However, higher cost is incurred, for example, vacuum consolidation and prefabricated vertical drain. Mechanical method involves changing the physical properties of the soil using fibrous material, which results in a composite material of soil-fibre with improved tensile strength. Chemical method uses chemical additive to enhance the strength by altering the bonding properties between particles such as polymeric resins (Tadayonfar, 2016), cement (Chan & Abdullah, 2006), and lime. It significantly increases the strength. However, this method is quite expensive and requires high cost, and chemical solution would dissipate through the soil pores after sometime.

Mechanical method by using fibrous material seems to provide better alternatives in soil improvement techniques. Soil-fibre composite possesses good tensile strength, thus capable of reducing the effect of consolidation (Hejazi, Sheikhzadeh, Abtahi, & Zadhoush, 2012). This technique is based on the principle of friction, i.e. the soil-fibre composite will be compacted thus the strength will increase as the contact surface between soil-fibre increases (Patle et al., 2017). Synthetic or natural fibre can be used, however, natural fibre is being bio-degradable and possesses long-term performance could be a denial. The option on selecting synthetic fibre is more visible for this purpose.

Some examples of synthetic fibres such as polypropylene, glass and plastic fibres are proven to be used to increase the strength of soil. Even though synthetic fibres are unable to absorb moisture in soil, this material can improve the strength due to robustness and high resistance to fatigue, physical damage, chemical solvents, bases and acids. Glass fibre is a fragile material that could suddenly fail. Meanwhile, polypropylene fibre is typically used as reinforcement in concrete and soil compared to plastic fibres (Senol, Banu, Etminan, & Demir, 2014). Polypropylene is excellent as it is strong, non-decomposable, ever- lasting, durable, and non-corrosive. Plastic fibre also possesses the same quality of polypropylene, but, with lower cost. Plastic strip is non-biodegradable, so it efficiently persists in soil for many years, thus making plastic fibre as the best option in this study.

.

3.0 METHODOLOGY

The flow chart of research methodology adopted in this study is presented in Figure 1.

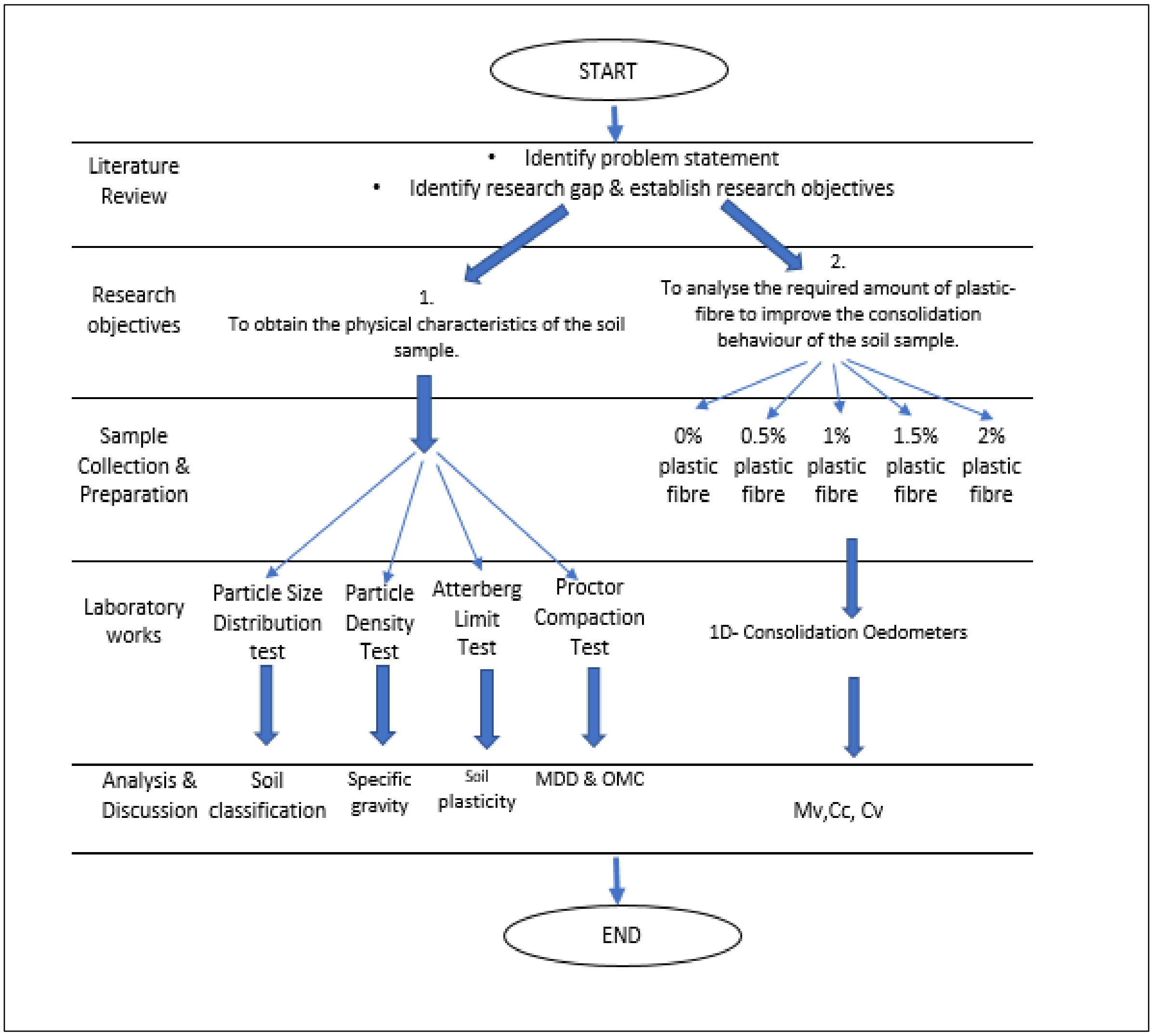

Figure 1. Flow chart of research methodology

3.1 Materials

The soil sample used in this study was collected at Simpang Empat, Kedah, Malaysia from a depth of 1 to 1.5 meters below the ground surface by using hand- auger. The soil was oven dried at the laboratory.

The reinforcement material i.e. plastic fibre (Figure 1) was easily obtained and cheap. During sample preparation process, the plastic fibre was cut into 25 mm to ease mixing and standardisation process. The plastic sample must be uniformly distributed in the soil-fibre interface, so that surface contact friction could be developed uniformly across the samples.

Figure 1. Plastic fiber used as soil-reinforcement (left), Plastic fiber mixed with soil sample.

3.2 Physical and Mechanical Properties Test

Physical property tests such as natural moisture content, particle size distribution (BS 1377-2:1990 Clause 9.2,9.3), plastic limit & liquid limit (Clause 5.3,5.4), particle density (Clause 8.3) were conducted to investigate the characteristics of the soil sample. Standard Proctor test (BS1377-4:1990 Clause 3.3) was conducted to determine the mechanical properties of the soil, i.e. maximum dry density, MDD, and optimum moisture content, OMC.

Then, all the samples for consolidation test were prepared at optimum moisture content to ensure standardisation of the sample. These samples were mixed and compacted with inclusion of plastic fibre 0.5%, 1%, 1.5%, and 2.0%, by mass fraction.

3.3 1-Dimensional Consolidation Oedometer Test

In this experiment, various loads were applied to the soil sample progressively to represent actual loading conditions at the field due to the change of effective stresses. This test was carried out by applying increments of vertical load statically to the sample and recording of the corresponding vertical displacement. During each loading increment, the change in the thickness of the sample against time was recorded. The time taken for each load to reach equilibrium depended on the soil and its consolidation characteristics. Once equilibrium was reached for each loading step, the next load increment was applied. The load was doubled at each increment, i.e. 25, 50, 100, 200, 400, and 800 kPa. Details of the procedure are referred to BS 1377-5:1990.

4.0 RESULT AND DISCUSSION

4.1 Soil Index Properties

Soil index properties indicates the physical properties and the types of soil sample. Table 1 shows the result of index test of the soil sample. According to British Soil Classification System (BSCS), the soil sample is classified as Silty Sand of Very High Plasticity.

Table 1. Index Properties of the soil sample

Characteristics	Index Properties
Natural Water Content (%)	28.76
Specific Gravity	2.79
Particle Size Distribution; Sand (%), Silt (%), Clay (%)	46.96, 44.76, 8.27
Liquid Limit, LL (%), Plastic Limit, PL (%)	71, 32
Optimum Moisture Content, OMC (%)	22
Maximum Dry Density, g/cm^3	1.566

4.2 Coefficient of Volume Change (m_v) and Compression Index (C_c)

Based on the 1D- consolidation oedometer test, the void ratio-stress curve and void ratio-log stress curve are plotted as shown in Figure 2. From the curves, the coefficient of volume change (m_v) and compression index (Cc) can be generated. These values are given in Table 2. The value is obtained from loading rate of 400kPa to 800kPa.

As the percentage of the plastic fibre increase, m_v also increase. However, at 2% inclusion of plastic fibre, m_v starts to decrease. Similar behaviour was observed for Cc. Initially, Cc increases as the percentage of plastic fibre increases and starts to drop at 1% inclusion of the fibre.

As reported by Laskar & Pal (2013), the usage of plastic strip is able to reduce the magnitude of m_v and Cc. The use of plastic fibre in soil will introduce additional bonding between the soil particles, which in turn, increases the shear strength of the compacted soil-fibre and automatically lessens the settlement.

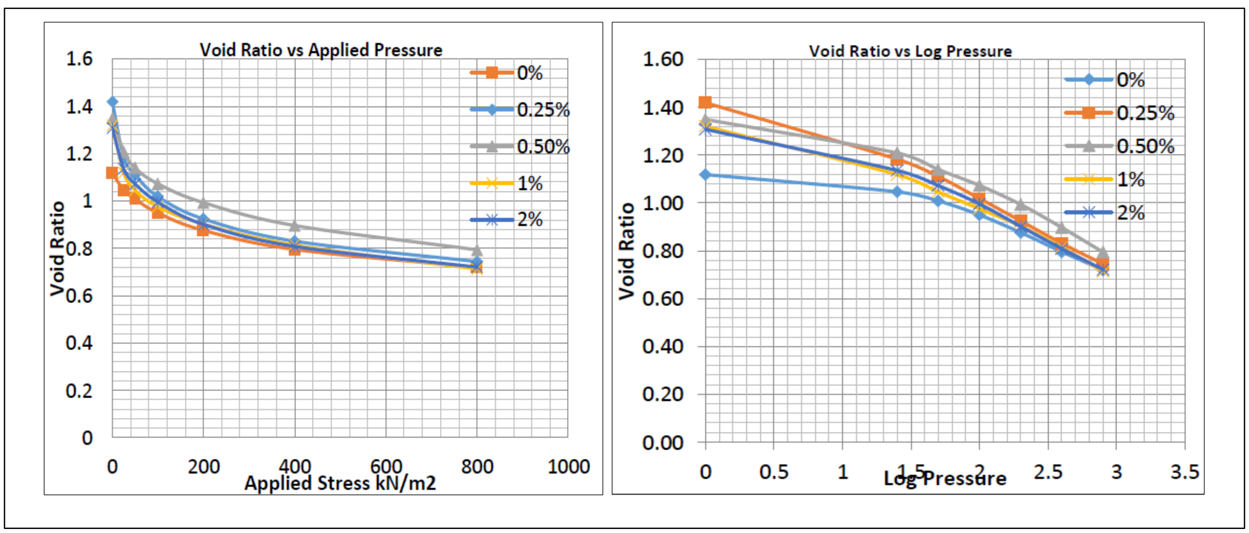

Figure 2. void ratio-stress curve (left) and void ratio-log stress curve (right)

Table 2 Coefficient of Volume Change (mv) and Compression Index (Cc) for Loading Rate at 400-800 kPa

Sample	Coefficient of Volume Change, mv (m^2/MN)	Compression Index (Cc)
Compacted soil sample without plastic fiber	0.111	0.253
99.75% compacted soil sample with 0.25% plastic fiber	0.124	0.287
99.5% compacted soil sample with 0.5% plastic fiber	0.143	0.341
99% compacted soil sample with 1% plastic fiber	0.254	0.339
98% compacted soil sample with 2% plastic fiber	0.127	0.290

4.2 Time Rate of Consolidation and Coefficient of Consolidation (C_v)

The time rate of consolidation is a stage of time where soil has achieved 90% of consolidation during the consolidation process. After this process, the soil will demonstrate a very slow and minimal change of thickness, indicating that the stabilization stage has been reached. Coefficient of consolidation (C_v) is used to describe the rate of consolidation, where the saturated soil experiences consolidation due to the pressure applied. Theoretically, C_v can be determined by using Taylor's Square Root Method or Casagrande Log Time method. In this study, Taylor's Square Root method was applied due to its simplicity. Figure 3 presents the graph of variation in the magnitude of the coefficient of consolidation (C_v) and the time rate consolidation of the soils at loading rate of 400 kPa.

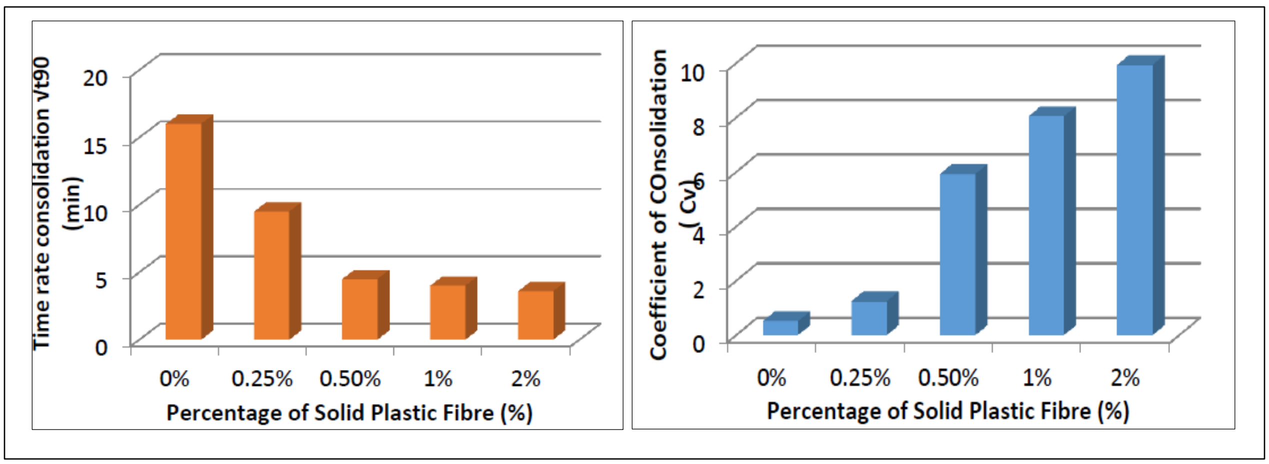

Figure 3 Time rate of consolidation (left) and Coefficient of Consolidation (right)

The plastic fibre reinforced soil gives small values of C_v after the first applied load of 25 kPa. According to Laskar & Pal, (2013), C_v is typically computed at the loading rate of 400kPa as the soil is at the final stage where the change in thickness is very small. The unreinforced soil has the lowest coefficient of consolidation (C_v). The highest value of C_v was 9.94 (mm^2/min), i.e. at 2% soil-plastic fibre mixture. The coefficient of consolidation increased as the percentage of the plastic fibre increased.

All soil-plastic fibre samples reached 90% of the consolidation process faster compared to soil sample alone. At loading rate of 25kPa to 50kPa, the consolidation process occured very fast. The quickest time rate of consolidation was 12.96 min at 2% of soil-plastic fibre. The results showed that the higher percentage of the plastic fibre, the faster time taken to reach 90% settlement.

According to Malekzadeh & Bilsel, (2012), the plastic fibres used in soil will result in the increase permeability of the soil due to the dispersion of the plastic fibre, and increased the porosity of soil. The rate of 1D consolidation was generally affected by the rate of pore water dissipation. Therefore, once the permeability increased, the rate of consolidation rose. Similar behaviour was observed by Kar, Pradhan, & Naik (2012), he found that coefficient of consolidation was influenced by the length and the percentage of the plastic fibre. On the other hand, the time rate of consolidation of the soil (t_{90}) decreased as the usage of the plastic fibres in the soil increased.

16 CONCLUSION AND FUTURE WORKS

The coefficient of volume changes (mv) of soil-plastic fibre reduced only after 2% of plastic fibre was added. Initially, the m_v increased due to insufficient reinforcement. The compression index Cc only reduced after 1% of plastic fibre was used. To avoid excessive settlement, the value of mv and Cc should be as small as possible.

Meanwhile, as the coefficient of consolidation (Cv) increases, the time taken for t_{90} decreases. Thus, the time required for the soil-plastic fibre sample to achieve primary consolidation decreases. The shorter time taken to achieve 90% consolidation indicates good achievement of the soil-plastic sample. In general, it can be said that the plastic fibre has the potential as settlement reducer at a given higher percentage of plastic fibre, i.e. more than 2%.

To further enhance the data obtained from this study, it is suggested to investigate the optimum value of plastic fibre to achieve maximum strength.

Acknowledgement

Special recognition is forwarded to Muhamad Azrul Aswad for his assistance during laboratory exercises i.e. Geotechnical Laboratory, UiTM Pulau Pinang, during completion of this study.

References

Chan, C., & Abdullah, S. H. (2006). Settlement Behaviour of a Cement-Stabilised Malaysian Clay. *6th International Conference on Case Histories in Geotechnical Engineering*, 1–6.

Hejazi, S. M., Sheikhzadeh, M., Abtahi, S. M., & Zadhoush, A. (2012). A simple review of soil reinforcement by using natural and synthetic fibers. *Construction and Building Materials*, *30*, 100–116. https://doi.org/10.1016/j.conbuildmat.2011.11.045

Kalliyath, J. V., Joy, J. T., Paul, J. M., & Vadakkel, A. M. (2016). Soil stabilization using plastic fibers. *International Journal of Science Tehnology & Engineering, 2(12).*

Kar, R. K., Pradhan, P. K., & Naik, A. (2012). Consolidation characteristics of fiber reinforced cohesive soil. *Electronic Journal of Geotechnical Engineering*, *17 Z*, 3861–3874.

Laskar, A., & Pal, S. K. (2013). Effects of waste plastic fibres on compaction and consolidation behavior of reinforced soil. *Electronic Journal of Geotechnical Engineering*, *18 H*, 1547–1558.

Malekzadeh, M., & Bilsel, H. (2012). Swell and Compressibility of Fibre Reinforced Expansive Soils. *International Journal of Advanced Technology in Civil Engineering*, *1*(2), 42–46.

Mallikarjuna, V., & Mani, T. B. (2016). Soil Stabilization Using Plastic Waste, *4th International Conference on Emerging Trends in Engineering, Technology, Science and Management, 2(12*), 2319–2322.

Muntohar, A. S., Widianti, A., Hartono, E., & Diana, W. (2013). Engineering Properties of Silty Soil Stabilized with Lime and Rice Husk Ash and Reinforced with Waste Plastic Fiber. *Journal of Materials in Civil Engineering*, *25*(9), 1260–1270. https://doi.org/10.1061/(ASCE)MT.1943-5533.0000659

Patle, D., Burike, M., Madavi, S. D., & Raut, S. (2017). Soil Stabilization Using Plastic Waste. *International Journal of Research in Science & International Journal of Research In Science & Engineering*, (April), 2394–8299.

Senol, A., Etminan, E., Yildirim, H., & Olgun, C. G. (2013). Improvement of High and Low Plasticity Clayey Soils Using Polypropylene Fibers and Fly Ash, *American Society of Civil Engineers*, 500–509. https://doi.org/10.1061/9780784478547.001

Tadayonfar, G., Shahmiri, N., & Bazoobandi, M. H. (2016). The Effect of Polyvinyl Acetate Polymer on Reducing Dust in Arid and Semiarid Areas, *Open Journal of Ecology*, 176–183.