

Settlement Behaviour of Peat Reinforced With Recycled Waste Tyre Granules

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Abstract. Peat is a problematic soil for having high organic content and high water content in nature. This soil is normally avoided for construction as it shows significant primary and secondary settlement even under moderate load. Ground improvement is conducted to improve peat properties by using cement column, soil replacement, chemical and biological stabilisation and others. However, some of these methods have their drawbacks for being non-sustainable to the environment, very costly, ineffectiveness and slow result performance. Alternative method using recycled waste tyre granules is seen as an innovative approach to reduce the settlement behaviour of peat in a more sustainable way. This paper investigates the effect of waste tyre granules on the settlement behaviour of peat. One-Dimensional consolidation test is carried out on natural sample and samples added with 5 % waste tyre granules with and without addition of sand as filler. The settlement curves for all samples do not show distinct separation between primary and secondary compression stages when using Casagrande's method. Sample which is reinforced with 5 % waste tyre granules and sand has lower compression index and swelling index compared to other samples. The coefficient of volume of compressibility for all samples is reduced with increasing stress levels.

1 Introduction

Peat is a dark brown or black colour highly organic soil which contains more than 75 % organic content. It is formed by decomposition of mosses, sedges, trees and other plants that grow in marshes and other waterlogged condition that has limited oxygen supply. The texture of peat is different from one location to another due to the fibre content, temperature and degree of decomposition [1]. Decomposition is a process which breakdown the original structure of the peat besides changing the chemical composition. The type of decomposition depends on the availability of oxygen supply which governs the rate of the process.

The water content of peat may range from 200 % to 700 % in West Malaysia but can also reach to 2000 % in some countries [2]. Peat contains fibres with loose and porous structure, which able it to hold considerable amount of water. Water is trapped as intercellular water within the micropores, macropores and adsorbed water [3].

As land becomes scarce due to population growth, the construction of roads, structure and infrastructures over this soft ground cannot be avoided. The development on peat is not a straightforward geotechnical solution like any other inorganic soil as the mechanical behaviour for soft mineral soils such as clay and silt can no longer be applied when the organic content is more than 20 % [4]. Failing of buildings to perform its function on poor ground condition may lead to unprecedented casualties to human life.

In the context of geotechnical problems, peat is very problematic when subjected to compressive stress as it unable to support a moderate load as it shows excessive settlement. The settlement of peat is divided into three different stages namely initial compression, primary compression and secondary compression. The initial compression occurs due to compression of pore gas and elastic compression of soil grains. Primary compression is developed as a result of dissipation of excess pore water pressure which causes an increase in effective stress and secondary compression is the additional settlement after primary compression is completed under constant effective stress [1]. Normally primary compression occurs rapidly while the secondary compression is the most significant settlement which contributes to the total settlement of peat. There are several factors which control the compressibility of peat such as fibre content, organic content, in-situ water content, void ratio, permeability, nature and arrangement of soil particles and inter-particle chemical bonding in some of the soils [5].

Many researchers have established several peat improvement methods such as excavation-displacement and replacement, ground improvement and reinforcement such as stage construction and preloading, stone columns, piles, vertical drains or by reducing driving forces by light-weight fill and deep stabilisation using chemical admixtures such as lime, cement and fly-ash, surface mattresses, surcharge loading, thermal methods and bio-mineralisation [6,7,8]. However, some of these methods have been criticised on the basis of

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high cost and ineffectiveness. For example, removal and replacement, compaction control, stone columns and surcharge loading are rather expensive and the use of cement is not sustainable for the environment.

Therefore, it is urgent to find a new method which is inexpensive, environmentally friendly, accessible and rapid treatment in order to improve the properties of peat ground. The usage of waste products such as tyre waste in various forms has been recently developed and being used in several geotechnical applications ranging from retaining structures, earth embankments, asphalt pavement and paving system, foundation beds and other applications [9]. A tyre is composed of rubber polymer materials strongly reinforced with synthetic fibres and high strength steel which produces a material having unique properties such as very high tensile strength, flexibility and high frictional resistance [10]. In Malaysia, the total waste produced annually is 8.2 million or 57,391 tonnes and has been considered as commercial waste as there are no specific regulations on its management [11].

Various research works on the usage of shredded tyre waste tyre chips for civil engineering projects have been reported recently especially for road and embankment construction [9,11,12,13,14,15]. Different types of soil were used to mix with 5 %, 10 %, 20 % and 30 % of shredded tyre chips either coarse material (sand) or fine materials (clay and peat) for soil improvement. Most of the researchers are looking at the strength behaviour, drainage properties, CBR values and compaction properties of the treated soil. The results obtained from Direct shear test suggest that cohesion and friction angle increased with increasing tyre proportions. Besides, the dry density reduced and optimum moisture content increased with increasing dosage of tyre. The CBR values also increased as the stiffness of the sample treated with tyre material improved significantly.

There is limited study investigating the effect of shredded tyre chips on the settlement behaviour of peat. Hence, the aim of this research is to investigate the effect of adding different percentages of tyre granules on compressibility behaviour of peat soil. Some samples were added with sand as filler for the purpose to limit the increase in coefficient of permeability in peat and tyre granules.

2 Materials and method

2.1 Materials

The peat used in this study was collected from a specific site in Selangor state of Malaysia. The site area is a farm area located along Jalan Johan Setia, Klang, Selangor as shown in Figure 1. Recycled waste tyre granules contain 0.03 % steel wires and nylon fibres passing 5-8 mm sieve with a density of 1.15-1.20 g/cm³ were used as reinforcing material. The tyre granules are shown in Figure 2.

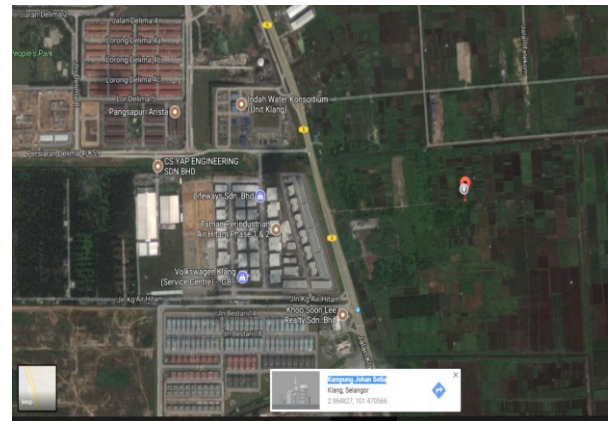


Fig. 1. The location of peat sample used in this study.



Fig. 2. Recycled waste tyre granules material.

2.2 Preparation of samples

Peat soil was firstly air-dry on a tray until reaching at least 200 % gravimetric moisture content. Then, partially dried peat was sieved on a 2 mm mesh sieve aperture in order to remove large particles. Particles which are smaller than 2 mm were used for preparing the admixtures. Drying organic material in high-temperature oven should be avoided in order to prevent degradation organic matter. The consistency of the sampling is very important for peat as the moisture content can easily dry out. Hence, the water content of the sample before mixing should always be checked regularly. In order to prepare the samples, around 700 g of peat soil were thoroughly mixed with 5 % waste tyre granules using a gloved hand for 10 minutes. In this research, 5 % waste tyre granules were used as this percentage is the minimal amount that can influence soil properties. The other sample was also prepared in the same manner, but sand particles were added at a constant amount in the peat and tyre granules mixture. The amount of sand added was half of the total weight of the peat soil. Each sample was then compacted for 27 numbers of blows in one layer using Standard Proctor Test. Then, the specimen was extruded from the compaction mould using 50 mm diameter and 20 mm height consolidation ring. All the

specimens were then tested for One-Dimensional Consolidation Test.

The details of the sample used in this study are shown in Table 1 below:

Table 1. Summary of physical properties test results.

Sample number	Sample description
1	Natural peat soil
2	Peat + 5 % waste tyre granules
3	Peat + 5 % waste tyre granules + 50 % sand

2.3 Experimental Program

2.3.1 Physical properties tests

Natural peat was tested for moisture content and specific gravity which in accordance to BS:1377:2 (1990) while for pH was based on BS:1377:3 (1990). The organic content and fibre content are following the ASTM-D2974-7a (Method C) [16] and ASTM-D-1997-91 standards [17].

2.3.2 Engineering properties tests

One-Dimensional test is based on BS 1377: Part 5: 1990. Loading pressures of 6, 12, 25, 50 and 100 kPa and unloading pressures of 200, 50 and 12 kPa were applied on natural peat, peat with 5 % tyre granules and peat with 5 % tyre granules with sand. For each stage of loading and unloading, samples were left for 3 days. This is to allow the development of secondary compression to be completed under constant effective stress. Once reaching the last stage, the samples were checked for the final moisture content.

3 Results and discussion

3.1 Physical Properties test

The peat obtained is a brownish black in colour containing decomposed plants such as leaves and stems. The natural moisture content of the sample is 617.9 % which seems reasonable for peat located in Peninsular Malaysia. According to [2], the range of moisture content for Peninsular Peat is between 200-700 %. The organic content is around 84.2 % which considered as peat for having more than 75 % as proposed by [4]. For fibre content, the peat sample consists of 47.7 % fibres which considered as Hemic Peat according to ASTM D 1997. Based on the von Post scale, the peat is classified as H5-H6 with an intermediate degree of decomposition and recognisable plant structure. Specific gravity of peat recorded is 1.38 which is within the typical range of peat reported by [2]. The pH of peat is around 3.02 and considered as very acidic according to [4].

3.2 Engineering properties test

The results of the One-Dimensional Consolidation test for all the tested samples are discussed as follows:

3.2.1 Settlement Curves

Typical time-settlement curves for one of the tested samples at different stress levels are shown in Figure 3. After 3 days of loading, the curves show almost flat profile for stress levels 6 to 25 kPa. This implies that the classical consolidation theories cannot be applied since the distinction between primary and secondary compression cannot be justified. However, at 100 kPa and 200 kPa, the curves are similar like Type 2 curve which indicated by [18] where no inflection point is identified which results to difficulty to estimate the end of primary compression time. Hence, the measurement of excess pore water pressure is necessary to overcome the problem. However, this is beyond the scope of this paper. The analysis of consolidation test results depends on the accuracy of estimating the end of primary compression either by using Logarithmic time fitting method (Casagrade's method), Square root time method (Taylor's method) and pore water measurements [19].

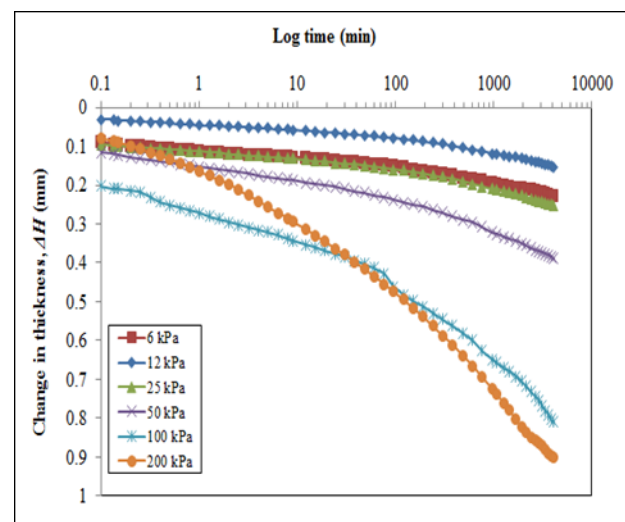


Fig. 3. Time-settlement curves for peat + 5 % waste tyre granules + 50 % sand.

3.2.2 Compression index and swelling index

Figure 4 shows the results of void ratio, e versus log effective vertical stress, $\log \sigma'_v$. The C_c and C_s values are obtained by determining the gradient of loading line (compression) and unloading (swelling) line respectively. As expected, sample which is mixed with 5 % waste tyre granules and constant amount of sand shows stiffer response as it represents the lowest C_c value compared to sample reinforced with 5 % waste tyre granules only. Original peat has the highest C_c among all the samples which describes the highest compressibility behaviour. Upon unloading, swelling capacity greatly reduced for peat treated with waste tyre granules and sand followed by peat reinforced with waste tyre

granules only and lastly non-reinforced peat. This suggests that adding waste tyre in natural peat able to reduce its compressibility and swelling capacity behaviour. The summary of the results is shown in Table 2.

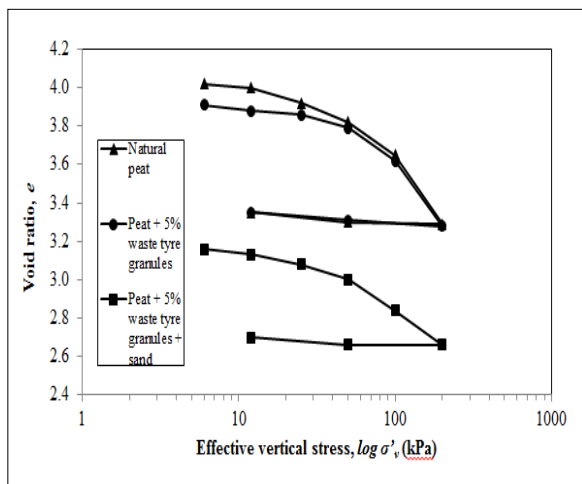


Fig. 4. Compression index, C_c and Swelling index C_s .

Table 2. Summary of Compression index, C_c and Swelling index, C_s for the tested samples.

Sample number	Sample description	C_c	C_s
1	Natural peat soil	0.88	0.05
2	Peat + 5 % waste tyre granules	0.85	0.04
3	Peat + 5 % tyre granules + 50 % sand	0.56	0.03

3.2.3 Coefficient of volume compressibility, m_v

A relationship between coefficient of volume of compressibility, m_v and effective vertical pressure, $\log \sigma'_v$ is established in Figure 5. It is observed that m_v values decrease when the effective vertical stress σ'_v increases for all the tested samples. Peat with 5 % waste tyre granules exhibits almost consistent volume change behaviour compared to other samples. Natural peat has the highest m_v values especially at 50 to 200 kPa which is approximately 0.72-0.74 m^2/MN compared to other samples. The uneven response of m_v values for natural peat and peat reinforced with 5 % waste tyre granules are most probably because of the drainage condition of the samples during consolidation stage. Some of the air voids contain in these samples are filled up with waste tyre granules and some are empty which result to different compressibility response.

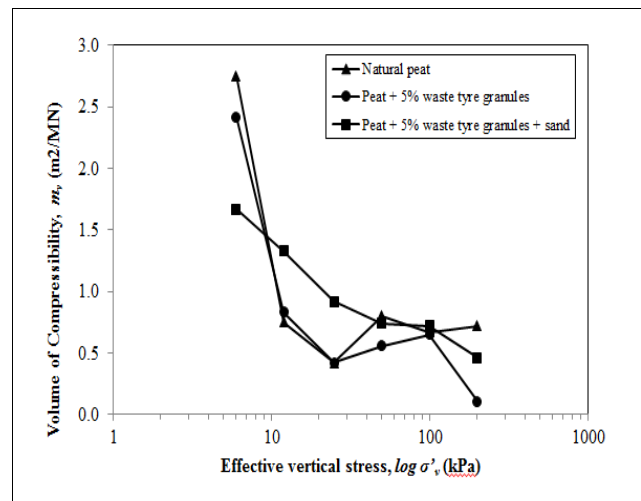


Fig. 5. Void ratio, e versus $\log \sigma'_v$ graph for peat with 5 % waste tyre granules and sand, peat with 5 % waste tyre granules and natural peat.

Conclusions

The following are the conclusions drawn from the experimental study:

1. The settlement-time curves for all samples do show the typical consolidation curve when plotted using Casagrande's method. The end of primary consolidation cannot be distinguished by using One-Dimensional Consolidation test without pore pressure measurements.
2. Adding recycled waste tyre granules able to improve the compressibility behaviour of natural peat soil. The addition of sand to sample containing natural peat and waste tyre further able to show better improvement in compressibility behaviour. Untreated sample shows the highest compression index (C_c), 0.88 followed by tyre treated sample, 0.85 and sand-tyre treated sample, 0.56.
3. Peat which is reinforced with waste tyre and sand shows almost consistent volume change compared to other samples. The natural sample shows the coefficient volume change, m_v is in the range of 2.75 to 0.72 m^2/MN while peat with waste tyre only is in the range of 2.42 to 0.11 m^2/MN . Peat reinforced with tyre waste and sand is in the range of 1.67 to 0.4

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