

PRELIMINARY STUDY OF SOIL-CEMENT PILING AS A NEW ALTERNATIVE IN LEVEE AND RIVER BANK STRENGTHENING

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Graphical abstract



Abstract

Malaysia has not yet experienced a totally severe levee failure as what have happened in other countries. However, flood has always been the major problem in Malaysia caused by several factors including weather condition, man-made and also including levee or bund failure. Therefore, in order to produce a new alternative to improve the structures of levees and river banks, this study on preliminary investigation of soil-cement piling is done to see the possibility of it to be used in the strengthening of levee or bund and river banks. The investigation focused on determining suitable soil-cement ratio to produce soil cement pile encased in PVC pipes in terms of axial capacity. The results show that the soil-cement mixture with 11% cement ratio produced the reasonable pile axial/compressive capacity.

Keywords: Flood, levee, river bank, soil-cement, pile

Abstrak

Malaysia dianggap sebagai sebuah negara yang bertuah kerana setakat ini belum pernah lagi mengalami kegagalan tetambak yang amat serius sepertimana yang pernah dialami oleh beberapa negara lain. Namun, banjir seringkali menjadi bencana utama yang melanda negara ini disebabkan oleh faktor semulajadi, perbuatan manusia termasuk juga kegagalan tetambak. Oleh itu, bagi menghasilkan alternatif baru untuk memperbaiki struktur tetambak dan tebing sungai, kajian awal mengenai cerucuk tanah-simen ini dijalankan untuk melihat keupayaannya untuk digunakan dalam kerja-kerja pengukuhan tetambak dan tebing sungai. Kajian ini memfokus kepada penentuan nisbah tanah-simen yang sesuai untuk menghasilkan cerucuk tanah-simen didalam paip PVC dalam terma kapasiti paksi. Keputusan yang diperolehi menunjukkan tanah-simen yang memiliki nisbah simen sebanyak 11% mempunyai keupayaan mampatan menasabah berbanding yang lain-lain.

Kata kunci: Gentian keluli, konkrit berbusa, konkrit ringan, mampatan, lenturan

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1.0 INTRODUCTION

Flooding can be caused either by natural or man-made factor. Man-made flood can be caused by levee failure, dam-breaching, war and other human activities [1]. In Malaysia, the Department of Irrigation and Drainage (DID or JPS) with the collaboration with

a few consultants including Jurutera Perunding Zaaba [2] has come out with Flood Control Remediation Plan for the betterment of flood problem in the country [3]. Dams, levees and riverbanks strengthening are among the most popular methods taken to prevent further severe flood since these structures can play such an

important role in controlling water flows or current [4], [5]. However, it seems like these structures sometimes have their own weaknesses that need to be taken care of as they are passive flood control measures. For example, levees and river banks are prone to undergo structural failures due to the water flows from the river [6], underground water condition or any other possible risks. Meanwhile, "Significant Hazard Potential" dam is defined as if there is any failure or mis-operation of a dam, it will not cause a loss of human lives, instead, economic lost, environmental damage, disruption of lifeline facilities and can impact other concerns [7].

Ten years ago, there was a severe hurricane Katrina occurred in New Orleans, Louisiana [8] which has caused severe damages and failures to a few parts of the levees in the city, which had held to a serious flooding as the consequence [9]. Since then, a lot of improvements have been done to improve the structure of levees, for example by using concrete piles. So far, concrete has always been used to increase the levee strength, for instance by installing concrete piles inside the levee. The comparison of the behaviour of square hollow section (SHS) tubes with concrete infill and rigid polyurethane foam (RPF) infill when undergoing transverse impact loading showed that concrete-filled tubes had the highest impact resistance and energy absorption capacity [10].

The usage of cement in soil stabilisation began with a trial in the early 1917 on Salisbury Plain [11]. Soil cement is usually used in soil stabilisation during road construction, basically to increase the reinforcement of subbase layer [12]. It is a type of construction materials that combines natural soil with a small amount of portland cement and water and is compacted to high density. When a normal portland concrete mixture requires the mix of cement, sand and water to form a paste to bind the aggregates together, soil cement otherwise will form a cement matrix with uncemented material nodules since the cement content is lower and thus leaving voids (Portland Cement Association [PCA]).

Even though soil cement is vulnerable to form cracks since it may be brittle and has a low tensile strength, it still has a good performance in compressive and shear strengths. It was suggested that in soil-cement mixture, the maximum value for liquid limit is 50% and the plasticity index is 30% with minimum value of 2.5% [13]. Apart from that, the effective unit water to the soil-cement mixture will affect its strength and density [14]. A compacted soil-cement mixture will continue to gain strength albeit the exposure to foreign substances, for example saline water, but only up to 90 days before it deteriorates [15]. Compacting soil cement in a PVC pipe can reduce the dependability to tensile strength and the compressive and shear strength can even be stronger. It is known that the maximum load of bakau pile is 10 kN or 1 tone whereas for reinforced concrete pile 1450 kN or 145 tone [16], so this study is done to construct a new alternative

which can provide a pile that at least meet up with the strength of a bakau pile.

2.0 EXPERIMENTAL SETUP

2.1 Preliminary Test on Soil

The clay soil used in this experiment was from a same source and a preliminary test was done to figure out the characteristic and properties of the soil. All the tests done in this early stage includes:

- i) moisture content test
- ii) particle size distribution test by using Sieve Test (wet and dry sieve)
- iii) liquid limit test
- iv) plastic limit test

2.2 Preparation of Soil-cement Mixture

The mixing of clay soil and cement was done at a specified percentage of soil to cement ratio. The mixture was then mixed manually by using hand until it was thoroughly blended together. The usage of concrete mixer was avoided since the existing concrete mixers in the concrete laboratory were the old ones and the residual cement in the mixers might disturb the soil-cement ratio content.

The samples were classified into a few groups according to the percentage of cement in the soil cement mixture, which were Group 1 for 0%, Group 2 for 5%, Group 3 for 8%, Group 4 for 11% and Group 5 for 15% of cement content with three samples in each group. The mixing and compaction were done in the same day to control the moisture content in the soil to not exceed the standard soil moisture for soil cement compaction. 15 cylinders of PVC pipe sized 4" in diameter is cut into 4" x 8" PVC cylinders. The soil cement mixture will be compacted in the PVC cylinders and left for 7 days for the cement to harden and so that the compressive and axial strength test can be done. 9kg of mixture is prepared for each classes of different cement percentage, 0%, 5%, 8%, 11% and 15%.

For 0%, there was no cement at all in the soil that was mixed and compacted in the PVC pipe. The compacted soil in the PVC cylinder will also tested for the compressive. Group 1 was done to be the control sample to compare the results from the other classes. Meanwhile for 5%, 450g of cement is added into the mixture, leaving the rest 95% of the mixture or 8550g to be the soil itself. The mixture was then being compacted into three different PVC cylinders. These samples were left for 7 days for the cement to harden and after that the compressive and axial strength tests will be done. The final result is taken from the average result obtained from the three samples in each group. The same procedures are used for 8%, 11% and 15%, differentiating in the amount of cement content and soil content. Figure 1 shows an example of mixing process during the preparation of samples



Figure 1 The example of mixing process during the preparation of 5% cement content in 9 kg soil-cement mixture

2.2 Compaction of Soil-cement Mixtures in PVC Cylinders

For the compaction process, the compaction was also manually done by using 50N sliding hammer from Mackintosh probing tool attached with a round steel plate of 10 cm diameter. This new method was designed to provide a suitable and perfect compaction to the soil cement mixture inside the cylinders as been shown in Figure 2. Three pieces of round steel plates with a diameter of 100mm are welded together to form a thicker steel plate that can withstand the drops from a 50N load during the compaction process. This steel plate is connected to the Mackintosh probe sliding hammer. The mixture is placed by three layers inside the PVC cylinder and in each layer, 10 drops of the hammer are blown to compact the soil cement until the three layers are completed.

To start the works in this stage, the first step was to prepare the equipments needed. For the compaction process, the compaction was also manually done by using 50N sliding hammer from Mackintosh probing tool attached with a round steel plate of 10 cm diameter. This new method was designed to provide a suitable and perfect compaction to the soil cement mixture inside the cylinders. Three pieces of round steel plates with a diameter of 4" are welded together to form a thicker steel plate that can withstand the drops from a 50N load during the compaction process. This steel plate is connected to the Mackintosh probe sliding hammer.

Later, the mass of each cylinder were taken and recorded. Since the density of the soil-cement mixture compacted in the cylinder needs to be calculated, only the total mass of the soil-cement without the cylinder would be used. The mixture was then placed by three layers inside the PVC cylinder and in each layer; 10 drops of the hammer were blown uniformly from 30 cm height to compact the soil cement until the three layers were completed as

been shown in Figure 3. However, the soil-cement mixture needs to be added if the compaction was not full up to the brim of the cylinder.



Figure 2 Throughout the process of compacting soil-cement mixture in the PVC cylinder



Figure 3 Throughout the process of compacting soil-cement mixture in the PVC cylinder

4.0 RESULTS AND DISCUSSION

4.1 Soil Properties

The soil is classified as a sandy fine soil based from the unified Soil Classification System. The particles distribution test was done based from the ASTM C136 standard for Sieve analysis by using wet method. The results show that the soil is sandy fine soil since more than 35% of the soil sample passed through the

0.063mm sieve. The graph in Figure 4 is increasing continuously which means that the soil particles passing through the sieves were decreased continuously as the sieve becomes smaller.

It is suggested that the suitable soil for soil-cement mixture is the one that has liquid limit value lower than 50%, where the plasticity index value should be within 2.5% to 30% based from the test done, the liquid limit obtained is a little bit higher than the optimum value. Nevertheless, albeit the high value of liquid limit, the plasticity index lied between the optimum values of which is needed for the best soil-cement mixture performance. Table 1 shows the detail results obtained from the preliminary tests of the soil.

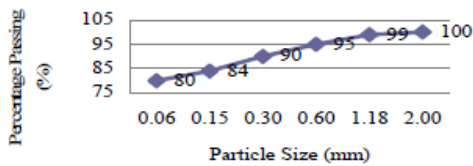


Figure 4 Particle size distribution curve (wet sieve)

Table 1 Properties of soil used

Percentage Passing 0.063mm Sieve: >35%	Sandy Fine Soil
Liquid Limit	54%
Plastic Limit	37.95%
Plasticity Index	16.06%
Percentage Passing 0.063 mm sieve	80%

4.2 Soil-cement Density

Every mixture either ordinary concrete mixture or soil-cement mixture have their own strength and durability depending on the density of the mixtures itself. Normally, the strength of ordinary concrete mixture will be stronger if the density is higher. The same formula goes to soil-cement mixture as both mixtures are using cement where the higher amount of cement in the mixture will result in the higher strength of cement mixture. Aside from cement content, the density of soil-cement mixture may be affected by the water content in the mixture, where for example, decrease after the water was hydrated by cement when the cement sets. It can be seen that the density of the soil-cement mixtures in the PVC pipes at day 7 decreases as the water content in the mixture has reduced. The data in Figure 5 shows the comparison of the average densities in chart.

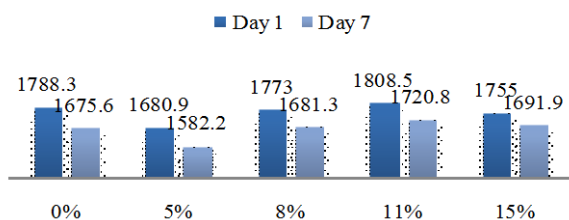


Figure 5 Density comparison of soil-cement (kg/m³)

4.3 Axial Strength Test

The soil-cement cylinders were tested after 7 days of being compacted, to ensure that the cement in the mixture has completely set out. The compressive test was done in the concrete laboratory by using universal testing machine that normally used to test the compressive strength concrete cubes. The machine was set to match the height of the PVC cylinders which were 8" or 20 cm and to be at 2.4 kN pace rate. An empty cylinder was first tested to observe the PVC pipe strength without the compacted soil-cement mixture in it. The data obtained for the empty PVC cylinder are shown in Table 2 below.

Table 2 Compression test of an empty PVC cylinder

Maximum Load	71.8 kN
Stress	9.136 kN/m²
Pace Rate	2.4 kN

Meanwhile, the graph in Figure 6 shows the result of the compressive test of the two samples of each cement percentage group. The data that has been put in this graph are the average value of the two samples from each group. The graph is seen as irregular as the maximum load of the soil-cement cylinder is at first decreased but increased afterwards but then decreased again. This pointed out that the soil-cement cylinder might have its own optimum soil-cement ratio which provides the highest compressive strength. Furthermore, the maximum load of 0% and all cement percentage groups are also higher than the empty PVC cylinder, stating that the PVC cylinders with compacted soil-cement mixture have higher compressive strength.

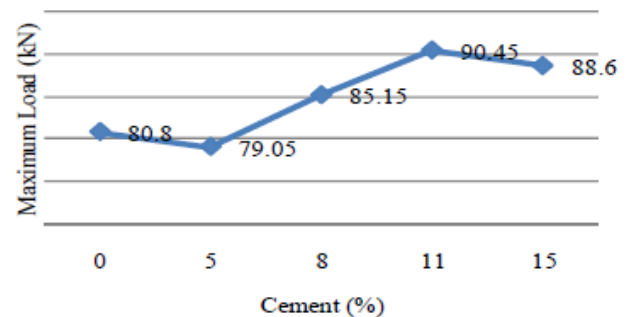


Figure 6 Cement (%) vs maximum load (kN)

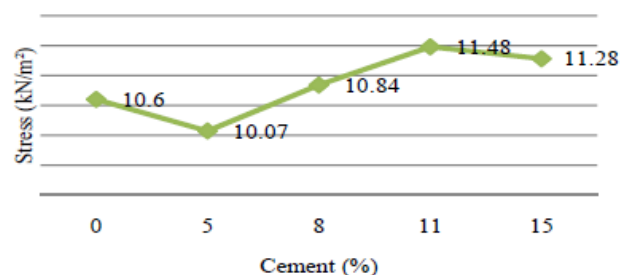


Figure 7 Cement (%) vs stress (N/mm²)

Moving on to the stress data obtained from the compressive test, the graph in Figure 7 shows its results. The stress values pointed in the graph are the average values from the two samples tested from each group. The relation between the maximum load and stress can be seen where the graph shows the same irregular pattern. The stress decreased when the maximum load decrease. In addition, all of the values are also higher than the stress value of the empty PVC cylinder.

5.0 CONCLUSION

The compressive or axial strength of the soil-cement pile is very important in this research since it is designed to be as an alternative pile to enhance the levee structure or can be used in river bank strengthening as well. In order to provide the same purpose as a conventional concrete pile, this soil-cement cylinder must have the best strength to withstand the huge compression load during piling process, considering that it will be piled down deep into the soil. Based on the obtained results, 11% of cement the soil-cement mixture seems to be the most optimum ratio as it results the highest maximum load and stress in the compression test at the age of 7 days. It has been stated that the purpose of this study was to figure out the possibility of soil-cement pile to be used in levee and river bank strengthening. The objective of this study has been achieved since the soil-cement pile has achieved higher maximum load than bakau pile (10 kN or 1 tone) even though lower than reinforced concrete pile (1450 kN or 145 tone). More tests should be done with different percentage of cement in the soil-cement mixture to investigate the most optimum soil-cement ratio needed to provide the best strength of soil-cement mixture to be used as a levee and river strengthening piles.

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