International Journal of Engineering & Technology, 7 (4.14) (2018) 343-347

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Compaction and CBR Characteristics of Sandy Clay Stabilised with Fibre-Mixed Binder

K.L. Tsai[1], C.M. Chan[1*], P.C. Tan[2]

[1]*Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, Johor, Malaysia.*
[2]*MTS Fibromat (M) Sdn Bhd, Selangor, Malaysia*
**Corresponding author E-mail: chan@uthm.edu.my*

Abstract

Soil chemical stabilization is an effective yet comparatively economical ground improvement method which involves injecting or blending a binder into the existing soil to enhance the geotechnical properties (e.g. strength and stiffness) for load-bearing purposes. The technique is especially beneficial for road construction works on clayey soil of limited load-bearing capacity such as rural roads. It required thick road base is critical to ensure long-term stability and performance. An endeavour is therefore undertaken to examine the effectiveness of a proprietary fibre-mixed binder in stabilizing soils (sandy clay) nature to serve as road base material. Kaolin was mixed with sand as the base soil at ratios of 0, 25 and 50% sand addition. The fibre-mixed binder was added at dosages of 1.5, 2.5 and 3.5% as recommended by the proprietor. Standard compaction test was first carried out to determine the optimum water content for each kaolin-sand mix. Then left to cure for 1, 3, 7 and 28 days before subjected to the California Bearing Ratio (CBR) test. From the test results, it was found that 2.5% binder addition was sufficient to attain the minimum CBR requirement of 30% for supporting a conventional flexible pavement, as per JKR standard. However, the 100% clay sample required higher binder dosages. Clearly sand particles in the soil contributed to the formation of skeletal scaffolding of the soil matrix, bound and supported by the fibre-mixed binder for enhanced strength properties. This was evident in the compaction test where 50% sand addition reduced the optimum water content by almost half compared to the 100% clay. Moreover 3-day curing could adequately strengthen all samples to attain the minimum CBR requirement (JKR standard), irrespective of the binder dosage used. In conclusion, it could effectively strengthen sandy clay soils within 3 days with dosages as low as 2.5%.

Keywords: *Civil, Chemical stabilization, CBR, Fibre-mixed binder, Standard compaction test*

1. Introduction

The residual soils comprise of sand, silt and clay in varying extents that on geographical setting of soil that cover more than 75% of Peninsular Malaysia's land. They are acted as the typical materials that normally applied to road and embankment construction in rural area of Malaysia [1]. The problematic soils such as clay soils usually reduce the durability of the pavement structure due to its low load bearing, high compressibility, high shrinkage and swelling characteristics [2]. It results in high construction and maintenance cost to increase the thickness of pavement and materials to enhance its serviceability and durability.
The durable pavement structure layers can produce a long lasting pavement to reduce the repairing and maintenance cost of rural road. The durable pavement structure depends on the design of pavement thickness, CBR value of road material used and its strength. The road construction works and designs are conducted in accordance with the JKR guidance. The strength performance of road can be improved by ground stabilization of road base by blending the chemical additives.
Chemical stabilization is the process involves injecting or blending a binder or additive into the existing soil to improve its geotechnical properties through a chemical reaction [3]. It can enhance its plasticity, unconfined compressibility strength, permeability and swelling pressure. The common binders that used in chemical stabilization are Portland cement, lime, fly ash, chloride compound and waste materials (fiber residue, fly ash and coal) added to cement the soil bodies, thereby increasing the strength and stiffness.
The oldest traditional stabilizer used in soil stabilization is lime that is reported by al-Swaidani et al [4]. Lime stabilization is the means of improving the soil strength and stiffness properties by adding lime such as hydrated lime ($Ca(OH)2$), limestone ($CaCO3$) or quicklime (CaO). It is beneficially modified several significant geotechnical properties of clayey soils. For instance, lime reduces the plasticity index (PI), increases the strength, California Bearing Ratio (CBR), workability and shrinkage whereas minimizes most swelling issues [5] [6].
The chemical stabilization technique is introduced in this research to overcome the problematic soil. It can enhance the clayey soil of limited load-bearing capacity by adding the fibre-mixed binder as recommended by a proprietor. The stabilized clayey soil is produced by this technique usually shows higher strength and stiffness compared to original clayey soil. This technique could be practical and applicable in road construction to produce a long lasting pavement with cost effectiveness to reduce the maintenance and repair cost of the pavement. Hence, the research is aim to help the industry to get the effective binder dosage to be used in soil stabilization to improve the strength of the clayey soil nature to serve as road base material.

Copyright © 2018 Authors. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

2. Experimental: Materials and Methods

2.1. Raw materials

Materials used were kaolin FM-C purchased from Kaolin (Malaysia) Sdn. Bhd and medium size sand particles. In addition, fibre-mixed binder that produced by MTS Fibromat Sdn Bhd was used in this study. It can be seen that kaolin is in white colour, sand in grey colour while fibre-mixed binder is brown in colour as illustrated in Figure 1.

(a) (b) (c)

Figure 1: (a) Kaolin FM-C, (b) Sand, (c) Fibre-mixed binder

2.2. Production of stabilised soil samples

In this study, Kaolin FM-C (clay) was mixed with sand as base soil for sandy clay at the ratios of 0 %, 25% and 50 % addition. Then fibre-mixed binders added with the dosages of 1.5 %, 2.5 % and 3.5 %. The binder is comprised of lime, cement, ionic compound and fibre. They were mixed thoroughly until they achieved a uniform colour before adding water. It processed the wet mixing process with adding the amount of water according to optimum moisture content obtained from standard compaction test and plus 2 % to each soil sample due to the addition of binder that will make faster the absorption rate of water before mixed completely. The wet mixing of soil sample and binder is aided by using the lab mixer. The stabilised soil samples were compacted to CBR mould and left for the curing process before subjected to California Bearing Ratio (CBR) test.

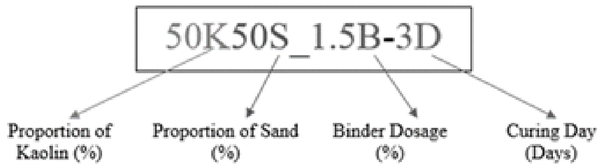
2.3. Curing Process

Portland Cement Association (1995) mentioned that the curing maintains a sufficient moisture for cement hydration of stabilized soil sample [7]. The freshly finished layer of stabilized soil sample must be properly cured to prevent the loss of water during curing period [8]. Curing is necessary to ensure continuous hydration of the stabilizer, reduce shrinkage and reduce the risk of carbonation by maintaining moisture and properly cured to prevent the loss of water for the stabilized samples. The curing period of 1, 3, 7, 28 days taken in this study is according to construction specification 29 [9]. The plastic sheeting used to completely cover the stabilized soil sample then covered another layer of moisture clothes to maintain the moisture condition at the joint as shown in Figure 2 (a). The covering of plastic sheeting can prevent the fresh surface not be eroded or otherwise damaged as showed in Figure 2 (b). The moisture clothes are regularly rewetted once in a week to maintain the moisture condition.

(a) (b)

Figure 2: (a) and (b) Curing method in the experiment

2.4. Identification sample code



2.5. Laboratory tests

The mechanical properties tests were carried out for all mixtures such as standard compaction test and California Bearing Ratio (CBR) test. The procedure of standard compaction test and California Bearing Ratio (CBR) are referred to BS1924: Part 2 (1990). The standard compaction test is conducted to determine the maximum dry density and optimum moisture content of stabilised soil sample. The 2.5 kg rammer and steel mould which 105 mm diameter and 115.5 mm height is used in the standard compaction test. The soil is applied by 27 blows from the rammer dropped from a height of 300 mm above it and distributed the blows uniformly over the surface of the soil.

The California Bearing Ratio (CBR) value is widely used in the design of pavement courses. It is the one of common test to determine the strength of soils. The stabilized soil samples are compacted into the 1L mould with the collar attached, in five equal layers using either the 2.5 kg rammer. Each layer of soils is compacted in 62 blows.

3. Results: Analysis and Discussion

3.1. Standard Compaction Test

The determination of maximum dry density and optimum moisture content for the different proportion of base soil samples such as sample 100K, 75K25S and 50K50S obtained from the standard compaction test to determine the liquid limit for preparation of the stabilized sample. The increase in moisture content increased the dry density until the maximum dry density attained. The maximum dry density and optimum moisture content are shown in Figure 3. There was a significant reduction of optimum moisture content by increasing the sand proportion of the sample. The sample 100K which contain 0 % sand is higher optimum moisture content and followed by sample 75K25S and sample 50K50S, i.e. 31.0 %, 22.8 % and 15.5 % respectively. However, the maximum dry density is increased by increasing sand proportion from sample 100K to sample 50K50S, i.e. from 1.28 Mg/m3 to 1.70 Mg/m3 thus the strength performance of the sample improved by increasing the shear strength. Basically, the increment of sand proportion will increase the maximum dry density but reduced the optimum moisture content. This is the indication of lesser demand for water for achieving the desired density in the field. The strength performance of samples can be discussed clearly for the further analysis in CBR test.

3.2. California Bearing Ratio

The strength of all sample can be obtained from California Bearing Ratio (CBR) test after 1, 3, 7 and 28 days curing as illustrated in Figure 4, 5, 6 and 7. It can be seen that the higher the proportion of sand results in higher CBR which increase from sample 100K (0 % sand) to sample 50K50S (50% sand). Because of the sand proportion gives a higher maximum dry density that causes the soil more brittle and bearing capacity to resist the load penetration. There has significant strength improvement (CBR value) for all treated samples (1.5 %, 2.5 % and 3.5 % binder) compared to control sample (0 % binder) as shown in Fig 4 (1-day curing). They also figured that the increase in binder dosage is not much influence the CBR value for the sample 100K (0% sand) and sample 75K25S (25 % sand) in Fig 5 (3-days curing) and Fig 6 (7-days curing). Thus, the addition of 2.5 % binder is sufficient for soil stabilization of the sample 100K and sample 75K25S. There has more significant binder effect in the sample 50K50S (50% sand) when admixed with binder dosage that greater than 2.5 % after 3-days curing and 28-days curing as shown in Fig 5 and 7.

The effect of the curing process is negligible on the strength improvement (CBR values) for all samples except the 28-days curing sample. It can be seen that the difference between 1-day and 7-days curing sample are approximately within 10% as shown in Fig 4 and 6. The 3-days curing is sufficient for all samples which are able to strengthen all samples with negligible improvement with prolonged curing to 7 days to attain CBR of 30 % for the conventional flexible pavement design of the road [10]. Besides, the highest CBR values are the sample 50K50S (50% sand). In road construction, it helps to speed up the curing process to early attain the minimum CBR requirement of 30 % in conventional flexible pavement according to JKR standard.

It cannot be denied as shown in Fig 4 that shows a drop in CBR value in sample 100K admixed with binder dosage from 1.5 % to 2.5 % then slightly increase for the further increase in binder dosage. It may be caused by the workmanship problem in the preparation of the sample.

Venkatasubramanian & Dhinakaran (2011) concluded that the bio-enzyme treated the soil with 28-days curing has higher CBR value, i.e. strength compare to the shorter curing day (14 days) as shown in Figure 8 [11]. The bio-enzyme treatment is more effective in treatment for silty clay soil compare to the sample 75K25S with stabilized with binder but the stabilization of sandy clay (Sample 50K50S) has a more significant increment in CBR compared to those treated with bio-enzyme. The CBR improvement of sample 50K50S can be seen that the square markers in Fig 4, 5, 6 and 7. Both treatment and stabilization effect is almost same for the clayey soil.

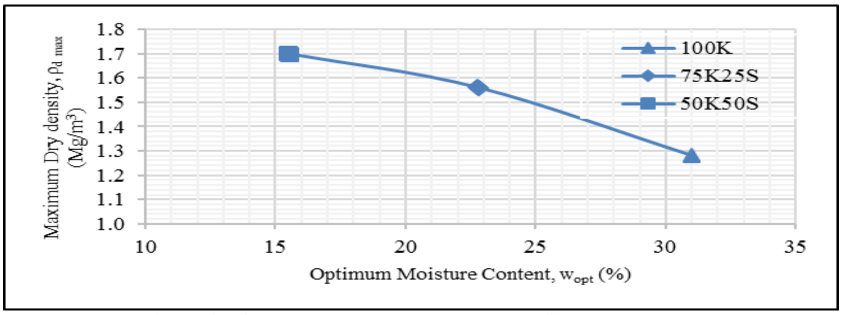


Figure 3: Relationship between Maximum Dry Density and Optimum Moisture Content

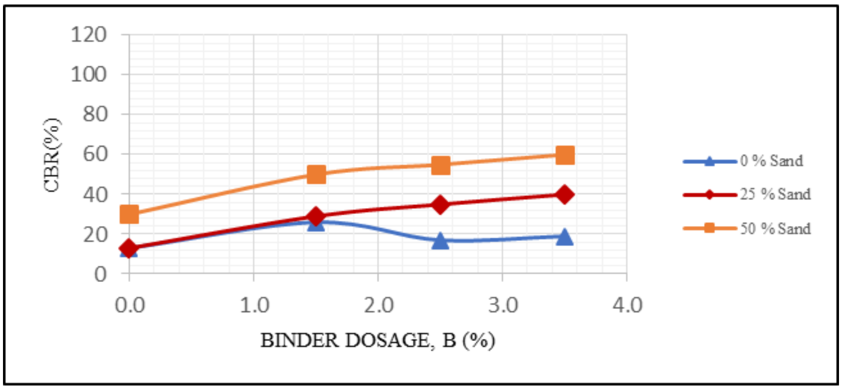


Figure 4: Effect of binder dosage on CBR for sample with 1-day curing

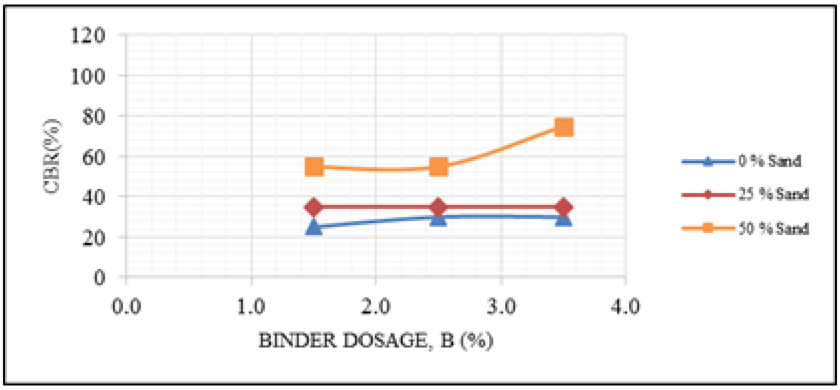


Figure 5: Effect of binder dosage on CBR for sample with 3-day curing

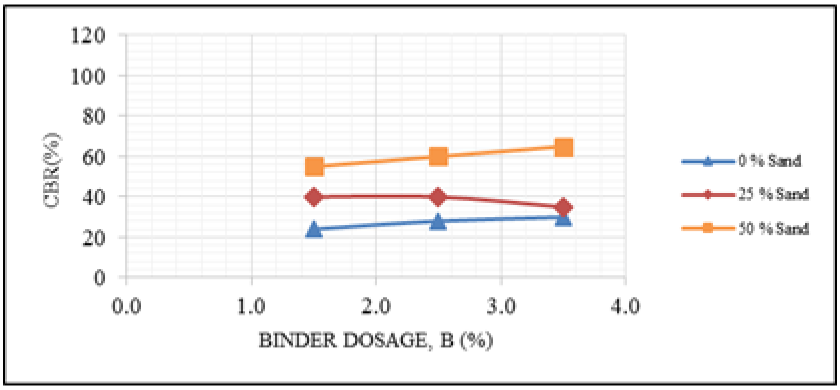


Figure 6: Effect of binder dosage on CBR for sample with 7-day curing

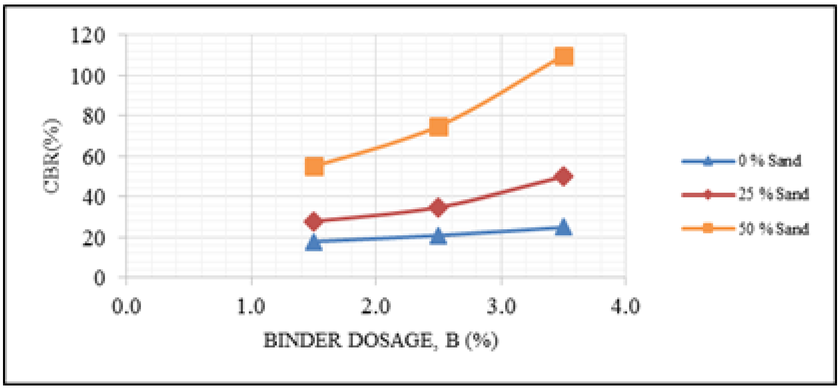


Figure 7: Effect of binder dosage on CBR for sample with 28-day curing

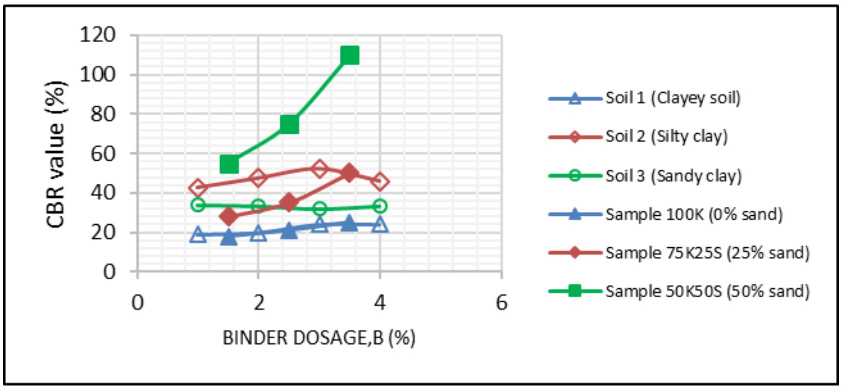


Figure 8: Comparison with Venkatasubramanian & Dhinakaran (2011)'s study

4. Conclusion

From the laboratory test for the clayey soil which stabilized by the fibre-mixed binder, was conducted to determine its improved geotechnical properties such as California Bearing Ratio (CBR) value. The strength performance of stabilized soil can provide evidence to get approval from JKR for the early completion of road construction without achieving the standard curing time of 7 days.

The 2.5 % binder can be used to stabilized the clayey soil admixed with 25 % and 50 % sand to attain the CBR requirement of at least 30 % for the conventional flexible pavement but the

100% clayey soil need more binder dosage to achieve the CBR requirement.

The 3-days curing is sufficient for all samples which are able to strengthen all samples with negligible improvement with prolonged curing to 7 days to attain CBR of 30 % for the conventional flexible pavement design of road.

The 50 % sand addition gives a threshold that result in significant strength enhancement in treated soil whereas 25 % sand addition is inadequate to cause significant changes to the soil's fabric.

Acknowledgements

I would like to express our deepest gratitude to Assoc. Prof. Dr Chan Chee Ming for her excellent guidance, idea, explanation, caring, patience, and supervise from the early to the end of this study. And also thanks to Mr. Tan Poi Chrong and MTS Fibromat Sdn. Bhd for their kindness to provide financial support to do the study.

References

[1] M. Taha, M. Hossain, and Z. Chik, "Geotechnical behaviour of a Malaysian residual granite soil," *Pertanika J. …*, vol. 7, no. 2, pp. 151–169, 1999.
[2] H. Canakci et al., "Strength and mechanical behavior of short polypropylene fiber reinforced and cement stabilized clayey soil," Procedia Eng., vol. 8, no. 2, pp. 123–138, 2016.
[3] E. O. Tastan, T. B. Edil, C. H. Benson, and A. H. Aydilek, "Stabilization of Organic Soils Using Fly Ash," J. Geotech. Geoenvironmental Eng., vol. 137, no. 9, pp. 819–833, 2011.
[4] A. al-Swaidani, I. Hammoud, and A. Meziab, "Effect of adding natural pozzolana on geotechnical properties of lime-stabilized clayey soil," *J. Rock Mech. Geotech. Eng.*, vol. 8, no. 5, pp. 714–725, 2016.
[5] C. D. . Roger and S. Glendinning, "Modification of clay soils using lime," *Gr. Eng.*, 1996.
[6] M. A. Sakr, M. A. Shahin, and Y. M. Metwally, "Utilization of lime for stabilization soft clay soil of high organic content," *Geotech. Geol. Eng. 2009*, 2009.
[7] Portland Cement Association, Soil-Cement Construction Handbook Engineering Bulletin. Portland Cement Association 1979, 1995.
[8] R. Robinson and B. Thagesen, Road Engineering for Development, Second edi. London: Spon Press, 2004.
[9] Natural Resource Conservation Service, "Construction Specification 29 — Soil Cement," United States Dep. Agric., no. January, pp. 1–8, 2009.
[10] JKR Manual, Manual On Pavement Design -ATJ(J)5-85. 2013.
[11] C. Venkatasubramanian and G. Dhinakaran, "Effect of bioenzymatic soil stabilisation on unconfined compressrve strength and California Bearing Ratio," Journal of Engineering and Applied Sciences, vol. 6, no. 5. pp. 295–298, 2011.