Journal of Engineering Science and Technology
Vol. XX, No. Y (Year) PPP - QQQ

PRELIMINARY INVESTIGATION OF CBR VALUE UTILIZING CRUSHED COCONUT SHELL AS ADDITIVE IN SILTY SAND

JESTIN JELANI[1,*], [1] MOHAMMAD FAIZAL ABDUL THALIB ABDULLAH[1], HAPSA HUSEN[1], MAIDIANA OTHMAN[1], ZULIZIANA SUIF[1], NORDILA AHMAD[1]

[1]Civil Engineering Department, National Defence University of Malaysia,
Sg Besi Camp, 57000, Kuala Lumpur, Malaysia
*Corresponding Author: jestin@upnm.edu.my

Abstract

Road surface deformation is influenced by the strength of its subgrade material. The deformation is measured based on the California Bearing Ratio (CBR), the ratio of the tested load to the standard load at a specific penetration. The focus of the present study is to determine the un-soaked CBR value of subgrade soil mixed with 0%, 2%, 4%, 6%, 8%, 10%, and 20% crushed coconut shell (CCS). The CBR values of the samples added with 2%, 4%, 6% and 8% CCS showed less significant increment ranging from -0.9% to 19% compared to the control sample. Nevertheless, the CBR value was observed to increase with higher percentages of CCS. The sample with 10% CCS demonstrated a considerably larger CBR value with 125% improvement or 2.3 times higher than the control sample. The highest CBR value was recorded by 20% CCS at 19.98%, that is 2.4 times higher than the control sample. Nonetheless, the high percentage of CCS resulted in reduced sample workability. For 6% CCS proportion, an increment of 14% moisture content reduced CBR value by 14% compared to the control sample. An optimal un-soaked CBR value of 13.12% was achieved for the addition of 10% CCS.

Keywords: CBR, Crushed Coconut Shell, Silty Sand, Subgrade.

1. Introduction

Subgrade layer is the lowest layer in a road structure that consists of native soil (see Fig. 1). The deformation of a road surface is dependent on the pavement quality and the strength of subgrade soil. The stability of subgrade soil is essential as it provides a stable foundation that supports the loads from the upper layers. In cases where the subgrade soil has a low bearing capacity or high swelling effect, treating the subgrade layer is necessary. Among the various methods for strengthening weak subgrade layers, the most common approach is replacing the weak soil layer with crushed granitic rocks [1]. Nevertheless, the technique is costly and employs non-renewable resources. Consequently, researchers have been attempting to discover cost-effective and sustainable materials to replace crushed granitic rocks.

Lime and cement have long been utilized to stabilize soil in road construction. The reaction of the materials in the presence of water and their long-term strength are well documented [2, 3]. For several decades, the research on soil stabilization investigated the utilization of polymers or geocomposite [4, 5, 6], fibrous materials [7, 8], silica sand [9], and chemical products [10, 11]. Recent studies investigated the feasibility of employing recycled materials and waste products, such as sugarcane bagasse, plastic strips, and rice husks, as alternative soil stabilizing materials due to their low cost and eco-friendliness [12, 13, 14]. The materials are also locally available, which could help reduce the disposal of waste materials.

In Malaysia, coconut shells are regarded as waste and are available in large quantities. Nevertheless, research on utilizing coconut shells for soil stabilization is limited. Amu [15] investigated the performance of coconut shell husk ash (CSHA) as a stabilizer in lateritic soil and found that adding 4% CSHA elevated the shear strength of the soil. Ramli [16] mixed clayey soil with coconut shell (CS) and rice husk ash (RHA), where the 20% RHA and CS mix increased the CBR value. Subsequently, Ramli [17] employed different percentages of crushed coconut shell (CCS) and eggshell powder (ESP) as additives in a weak subgrade soil. The optimum California Bearing Ratio (CBR) value was achieved with 4% CCS and 3% ESP.

Ikeagwuani [18] conducted a comparative study on the effects of coconut shell ash (CSA) and husk ash (CHA) as admixtures on lime stabilized lateritic soil. The stabilized lateritic soil incorporated with CSA exhibited a higher CBR value than the soil added with CHA. Oluwafemi [19] published experimental data on coconut shell powder (CSP) effects on lateritic soil. The report indicated that up to a certain percentage, the additive improved the soil properties and decreased at higher percentages of CSP. In another investigation, James [20] analyzed the effects of employing CSP mixed with lime on expansive soil and focused on the mineralogy and microstructure of the mixture. Recent studies reported the effects of utilizing coconut shell charcoal (CSC) in improving the bearing capacity of clay soil [21], and examined the effects CCS and CSA curing time of [22]. Consequently, the present study focuses on determining the CBR value of silty sand, the subgrade soil, added with varying percentages of CCS as the additive.

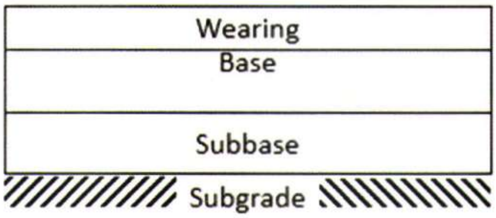

Fig. 1. Structure of road construction

2. Materials and Methods

Several procedures and tests are performed on the soil and CCS to prepare and characterise the materials. Among the tests are sieving, density, moisture content and CBR value.

2.1. Preparation of materials

The disturbed soil sample was obtained from the road construction site at the National Defense University of Malaysia (NDUM) at an approximate depth of 1.5m. The disturbed soil sample was kept in airtight plastic containers to preserve the natural moisture content, as shown in Fig. 2(a) and (b). The soil test was performed according to the procedures described in previous paper [23, 24], based on the British Standard, BS1377:1990.

The CCS, as shown in Fig. 3, is purchased from a local supplier and treated by removing the excessive husk before being air-dried. The size of the CCS utilized is ranged between 10 and 15 mm, according to [16]. The CCS was mixed into the soil sample in varying percentages, consist of 0%, 2%, 4%, 6%, 8%, 10%, and 20% of the sample weight. The sample without CCS (0%) was employed as the control sample.

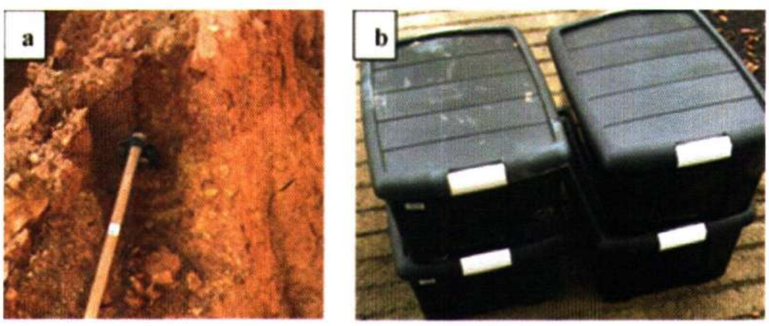

Fig. 2. (a) Soil sample collection nearby the campus road site (b) The soil samples were placed in airtight plastic containers.

Fig. 3. The CCS samples

2.2. California Bearing Ratio Test (CBR)

The strength of a subgrade layer is measured based on the CBR value. The value indicates the ratio of the test load to the standard load at 2.5 mm and 5.0 mm penetrations. The CBR values at 2.5 mm and 5.0 mm penetrations were calculated according to Eq. (1) and (2) respectively. The CBR test conducted in the current study followed the Malaysian Standard, MS1056:PART4:2005.

$$CBR_{(2.5mm)} = \frac{Load_{(2.5mm)}}{13.24kN} x100\% \quad (1)$$

$$CBR_{(5.0mm)} = \frac{Load_{(5.0mm)}}{19.96kN} x100\% \quad (2)$$

As shown in Fig. 4(a), the soil sample being weighed. On average, each soil sample was 5 kg. The soil samples were then mixed thoroughly with varying proportions of CCS before being divided into five equal parts (see Fig. 4(b)). Figure 4(c) shows the mixed specimens in a CBR mould with a 152 mm internal diameter and 127 mm tall. A 4.5 kg automatic rammer was utilized to compact the soil specimens with 62 blows, and the process was repeated for four consecutive layers, as demonstrated in Fig. 4(d). Figure 4(e) illustrates the compacted samples being weighed and placed on the CBR machine. The samples were evaluated in an un-soaked or a dry test condition to represent the condition of subgrades in normal rainfall.

A 4.5 kg annular steel ring placed on the top of the sample surfaces before performing the CBR test (see Fig. 4(f)). The assessment was carried out by penetrating the top and bottom parts of the specimen at a rate of 1 mm/min with a cylindrical plunger. In the present study, two soil samples were prepared for each percentage of CCS, which totalled to 14 samples. The average value of the two soil samples was documented as the overall CBR value.

The samples were then removed from the mould and moisture content was measured at the centre of specimen, as demonstrated in Fig. 4(h–i). These processes were repeated for each CCS percentage.

Fig. 4. The CBR test procedures according to MS1056:PART4:2005

3. Results and Discussion

The result of sieve analysis test for soil is shown in Fig. 5. The soil particle size distribution comprises of 10% clay, 34% silt, 46% sand, and 10% gravel. The soil sample is classified as Silty SAND based on the British Soil Classification System (BSCS). The soil particle density obtained from pycnometer test was 2.62 Mg/m^3.

The summary of un-soaked CBR test for soil with varying CCS percentages is shown in Fig. 6 and Table 1. The load required for 2.5 mm and 5.0 mm penetrations are determined from the graph and the average of the two readings are the final CBR values. The increase of CCS percentage in soil sample tends to increase stress required for constant penetration in the CBR test. These increments result from particle bonding between soil and CCS, allowing the soil-CCS mixture to withstand higher load.

The soil sample that contained 20% CCS recorded the highest CBR value of 19.89%, 2.4 times higher than the control sample. The high proportion of CCS relative to the quantity of soil restricted penetration of the plunger into the soil at the beginning of the test, resulting in a high CBR value. However, the mix proportion exhibited low workability where some CCS were expelled from the mould during compaction due to its difficulty to compact. Observation indicated that the mix proportion was not feasible for future studies.

The samples incorporated with 2%, 4%, 6% and 8% CCS showed less considerable changes in the CBR values than the control sample, with approximate improvement ranging from -0.9 to 19%. Meanwhile the soil sample with 10% CCS recorded a considerable CBR value increase with 125% improvement or 2.3 times higher than the control sample. The 10% CCS proportion recorded in this study shows almost similar results in previous investigations that combined 4% CCS with 3% eggshell powder [17] and 8% coconut shell charcoal [21].

The CBR value and the moisture content of the samples with varying CCS percentages are represented in Fig. 7. The addition of 6% CCS reduced the CBR value by almost 14% compared to the control sample. The observation might be due to the slight increase in moisture content in the sample, which was 14%. With the moisture content being the highest, this could be an indication that moisture content has an influence on CBR value. A previous report confirmed the observation that moisture content could reduce soil strength [2].

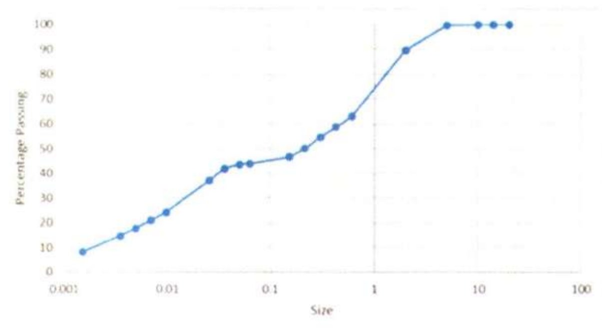

Fig. 5. The particle size distribution of the Silty Sand.

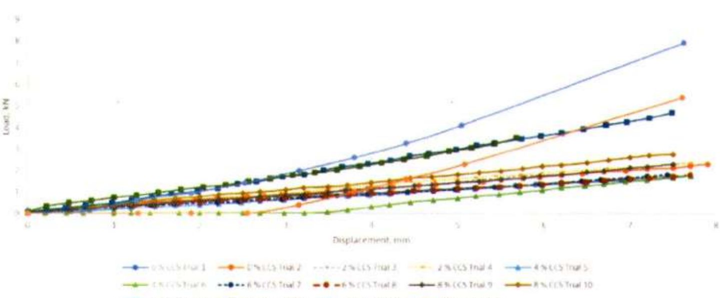

Fig. 6. Compilation of CBR test results for all mix proportions

Table 1. The CBR test data.

% of CCS	Trial No	Standard Load	Load Obtained from the Test	Calculated CBR Value	Average CBR Value	Final CBR Value
0	1	13.24	0.65	4.9	5.21	5.83
		19.96	1.10	5.5		
	2	13.24	0.78	5.9	6.45	
		19.96	1.40	7.0		
2	3	13.24	0.60	4.5	5.65	6.30
		19.96	1.35	6.8		
	4	13.24	0.78	5.9	6.95	
		19.96	1.60	8.0		
4	5	13.24	0.50	3.8	4.64	6.85
		19.96	1.10	5.5		
	6	13.24	1.04	7.9	9.06	
		19.96	2.05	10.3		
6	7	13.24	0.55	4.2	4.83	5.03
		19.96	1.10	5.5		
	8	13.24	0.62	4.7	5.22	
		19.96	1.15	5.8		
8	9	13.24	0.58	4.4	5.82	6.96
		19.96	1.45	7.3		
	10	13.24	0.95	7.2	8.10	
		19.96	1.80	9.0		
10	11	13.24	1.40	10.6	12.80	13.12
		19.96	3.00	15.0		
	12	13.24	1.50	11.3	13.43	
		19.96	3.10	15.5		
20	13	13.24	2.00	15.1	19.08	19.89
		19.96	4.60	23.0		
	14	13.24	2.10	15.9	20.71	
		19.96	5.10	25.6		

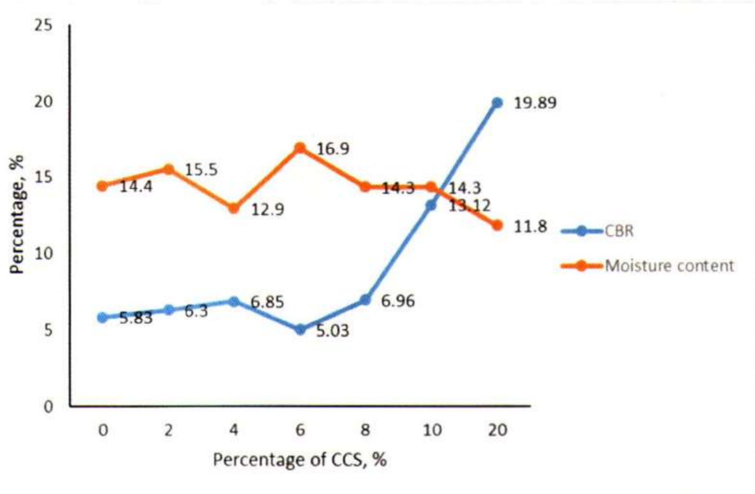

Fig. 7. The CBR value and moisture content with varying percentages of CCS.

4. Conclusion

The present study conducted a preliminary investigation to determine the feasibility of utilizing CCS in subgrade soil stabilization. Varying percentages of CCS based on the weight of the soil sample, 0%, 2%, 4%, 6%, 8%, 10%, and 20%, were added. The samples with 2%, 4%, 6% and 8% CCS showed less considerable changes in the CBR values than the control sample, with approximate improvement ranging from -0.9 to 19%. The soil mixed with 20% CCS demonstrated improvement 2.4 times higher than the control sample. Nevertheless, the incorporation of higher percentages of CCS reduced the workability of the soil sample. The CBR values for the soil samples mixed with 6% CCS indicated a 14% increase in moisture content, resulting in reduced soil strength almost 14% in comparison to the control sample. The soil sample with 10% CCS recorded a considerable increase in the CBR value with 125% improvement or 2.3 times higher than the control sample.

Acknowledgments

The authors would like to thank to the National Defence University of Malaysia for providing financial support for this research under grant number UPNM/2015/GPJP/2/TK/11 and the technical staff of Geotechnical Laboratory of Center of Excellent for Engineering and Technology, Malaysia (CREaTE) for corporation given through this study.

References

1. Yuan, P.; Zhou, R.B.; Dong, Z.L.; and Lou, Y. (2014). Influence on CBR for graded crushed rock on the base of port. *Advance Material Research*, 838–841, 962 – 966.
2. Afrin, H. (2017). A review on different types soil stabilization techniques. *International Journal Transportation Engineering and Technology*, 3(2), 19.

3. Ghobadi, M.H.; Abdilor, Y.; and Babazadeh, R. (2014). Stabilization of clay soils using lime and effect of pH variations on shear strength parameters. *Bulletin of Engineering Geology and the Environment*, 73(2), 611–619.
4. Huang, J.; Kogbara, R.B.; Hariharan, N.; Masad, E.A.; and Little, D.N. (2021). A state-of-the-art review of polymers used in soil stabilization. *Construction and Building Materials*, 305(August), 124685.
5. Othman, M.; Frost M.; and Dixon N. (2018). Stability performance and interface shear strength of geocomposite drain/soil systems. *AIP Conference Proceedings*. Malaysia, 1-7.
6. Tao, G.; Yuan, J.; Chen, Q.; Peng, W.; Yu, R.; and Basack, S. (2021). Chemical stabilization of calcareous sand by polyurethane foam adhesive. *Construction and Building Materials*, 295(2021), 123609.
7. Al-Saray, N.A.; Shafiqu, Q.S.; and Ibrahim, M.A. (2021). Improvement of strength characteristics for sandy soils by polypropylene fibers (PPF). *Journal of Physics: Conference Series*, 1895(2021), 012016.
8. Nezhad, M.G.; Tabarsa, A.; and Latifi, N. (2021). Effect of natural and synthetic fibers reinforcement on California bearing ratio and tensile strength of clay. *Journal of Rock Mechanics and Geotechnical Engineering*, 13(3), 626–642.
9. Mousavi, S.E.; and Karamvand, A. (2017). Assessment of strength development in stabilized soil with CBR PLUS and silica sand. *Journal of Traffic and Transportation Engineering*, 4(4), 412–421.
10. Jerez, L.D.; Gómez, O.E.; and Murillo, C.A. (2018). Stabilization of Colombian lateritic soil with a hydrophobic compound (organosilane). *International Journal Pavement Research and Technology*, 11(6), 639–646.
11. Noolu, V.; Heeralal, M.; and Pillai, R.J. (2018). Multi-scale laboratory investigation on black cotton soils stabilized with calcium carbide residue and fly ash. *The Journal of Engineering Research*, 6(4), 1-15.
12. Kumar, S.; Singh, R.P.; and Paswan, S.K. (2022). Strength and impact of rice husk ash on expansive soil by using soil stabilization. *Lecture Notes Civil Engineering*, 154, 73–80.
13. Garg, R.; Biswas, T.; Alam, M.D.D.; Kumar, A.; Siddharth, A.; and Singh, D.R. (2021). Stabilization of expansive soil by using industrial waste. *Journal of Physics: Conference Series*, 2070(1).
14. Gnana, P.G.; and Venkata, K.G. (2022). Strength behavior of lime stabilized soil reinforced with waste plastic strips. *Proceeding of Indian Geotechnical Conference. Andhra University, India*. 419–428.
15. Amu, O.O.; Owokade, O.S.; and Shitan, O.I. (2011). Potentials of coconut shell and husk ash on the geotechnical properties of lateritic soil for road works. *International Journal of Engineering Technology*, 3(2), 87–94.
16. Ramli, R.; Shukur, N.A.A.; Walid, T.I.A.M.; and Idrus, J. (2018). Engineering properties improvement of clayey soil using rice husk ash and coconut shell for road works. *AIP Conference Proceeding*. Malaysia, 020030.
17. Ramli, R.; Yahaya, N.N.; Bakar, N.N.A.A.; Dollah, Z.; Idrus, J.; and Abdullah, N.H.H. (2019). Effectiveness of crushed coconut shell and eggshell powder to act as subgrade stabilizer. *Journal of Physic : Conference Series*, 1349(1), 1–9.
18. Ikeagwuani, C.C. (2019). Comparative assessment of the stabilization of lime-stabilized lateritic soil as subbase material using coconut shell ash and coconut husk ash. *Geotechnical and Geological Engineering*, 37(4), 3065–

3076.
19. Oluwafemi, I.J.; Laseinde, T.O.; and Akinwamide, J. (2019). Data showing the effects of geotechnical properties of lateritic soil mixed with coconut shell powder in Ado-Ekiti, South Western Nigeria. *Data in Brief*, 24, 103861.
20. James, J. (2020). A micro-level investigation of optimum lime-content stabilized expansive soil amended with organic coconut shell powder. *Slovak Journal of Civil Engineering*, 28(1), 1–10.
21. Andriani; R.Y; and Permana, D. (2021). Utilization of coconut shell charcoal to improve bearing capacity of clay as subgrade for road pavement. *IOP Conference Series Earth Environment Science,* 832(1), 1–8.
22. Ramli, R.; Mansor, N.A.W.; Idrus, J.; Mansor, S.; and Abdullah, N.H.H. (2021). Effects of curing time using crushed coconut shell (CCS) and Coconut shell ash (CSA) as additive to improve lateritic soils. *IOP Conference Series Material Science Engineering*, 1144(1), 012090.
23. Jelani, J.; Baharudin, S.; Othman, M.; Daud, M.N.M; Ishak, A.S.A; and Yahya, M.A. (2021). Preliminary investigation of the effect of surcharge load and distance on non- homogenous man-made slope. *Jurnal Kejuruteraan SI*, 4(1), 101–107.
24. Jelani, J.; Hah, M.S.A.; Daud, M. N.M; Ahmad, N.; Othman, M.; and Sabri, W.M.S.W.M. (2021). Stability analysis of a man-made slope: a case study on the UPNM campus, Sg Besi, Kuala Lumpur. *Environment Science and Engineering*. Springer, Cham.